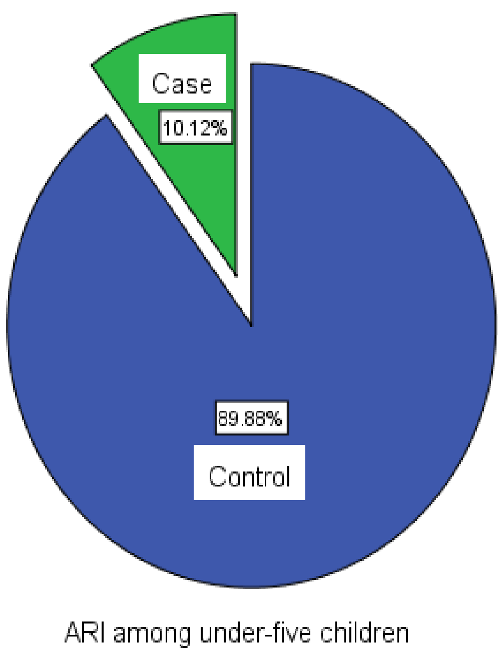
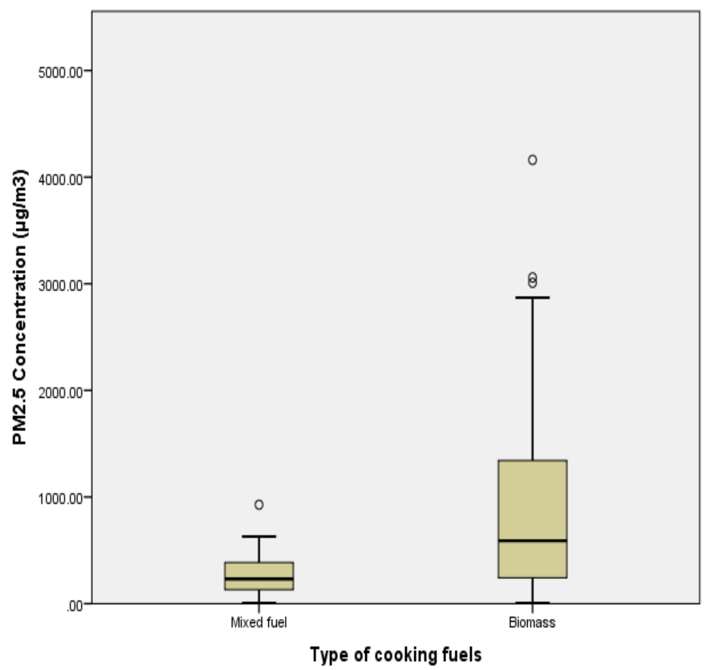
HOUSEHOLD AIR POLLUTION AND ITS HEALTH EFFECTS AMONG UNDER-FIVE CHILDREN IN WOLAITA SODO, ETHIOPIA

AMHA ADMASIE





Dissertation for the Degree of Doctor of Philosophy (PhD) in Public Health

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HOUSEHOLD AIR POLLUTION AND ITS HEALTH EFFECTS AMONG UNDER-FIVE CHILDREN IN WOLAITA SODO, ETHIOPIA

A PhD dissertation submitted to the school of Graduate studies of Addis Ababa University, in partial fulfillment of the requirements for the Degree of Doctor of Philosophy (PhD) in Public Health

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Household Air Pollution and Its Health Effects among Under-Five Children in Wolaita Sodo, Ethiopia

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Dedicated to my late father, ***Admasie Gelaye***

ORIGINAL PAPERS

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II. Amha Admasie, Abera Kumie, Alemayehu Worku, Wubshet Tsehayu. Household Fine Particulate Matter ($PM_{2.5}$) Concentrations from cooking fuels: the case in an urban setting, Wolaita Sodo, Ethiopia. Air Qual Atmos Health, June 2019, Volume 12, Issue 6, pp 755-763. https://doi.org/10.1007/s11869-019-00700-0.

III. Amha Admasie, Abera Kumie, Alemayehu Worku, Wubshet Tsehayu. Determination of the level, characteristics and associated factors of household CO in biomass fuel users, Wolaita Sodo town, Ethiopia. (BMC Public Health, PUBH-D-19-00739_ Under-review)

ACRONYMS AND ABBREVIATIONS

ALRTI	Acute Lower Respiratory Tract Infection
ANC	Antenatal Care
ARI	Acute Respiratory Infection
AQG	Air Quality Guideline
CEIHD	Center for Entrepreneurship in International Health and Development
CO	Carbon Monoxide
COHb	Carboxy-hemoglobin
COPD	Chronic Obstructive Pulmonary Disease
EDHS	Ethiopian Demographic Health Survey
HAP	Household Air Pollution
HAQ	Household Air Quality
IAP	Indoor Air Pollution
IAQ	Indoor Air Quality
LBW	Low Birth Weight
LPG	Liquefied Petroleum Gas
PM	Particulate Matters
PPS	Probability Proportional to Size
SNNPR	Southern Nations, Nationalities and Peoples Region
UCB	University of California Berkeley
UCB-PATS	University of California, Berkeley-Particle and Temperature Sensor
UCB-PM	University of California Berkeley-Particle Monitor
UPAS	Ultrasonic Personal Aerosol Sampler
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

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ABSTRACT

Background: Household air pollution is among the top ranked global public health concern particularly in developing nations, like Africa. Eighty percent of the population of sub-Saharan Africa and 90% of the Ethiopian population use biomass fuels for cooking. It is linked to many health problems including acute respiratory infection in children. The cause of this health problems is attributable to many factors including household air pollution. Acute respiratory infection is the most common illnesses in childhood, comprising as many as 50% of all illnesses in children less than 5 years old in the world. Household air pollution is still a big problem in developing countries. In Ethiopia, pneumonia alone contributed to 27% of all illness and 18% of all deaths to under-five children. Exposure assessment on indoor air pollution, specifically linked to acute respiratory infection is limited in Ethiopia.

Objective: To assess household air pollution and its health effects among under-five age children in Wolaita Sodo town, Ethiopia.

Methods: A community-based unmatched case-control and cross-sectional study design were used in the study. Census has been conducted prior to the actual data collection to specify sampling frame. One thousand one hundred forty-four (1144) children with cases to controls ratio of 1:3 (i.e. 286 cases and 858 controls) aged 0-59 months paired with their mothers were participated in the study. Cases are defined as a child who fulfilled the world health organization criteria of acute respiratory infection (i.e. a child who suffered from cough, followed by rapid breathing in the two weeks that preceded the survey date), while controls are a child who is free of any complaints of respiratory illnesses in the two weeks that preceded the survey date. In an eleven Kebele (the smallest administrative structure/unit of the government) in the town, six Kebeles were selected randomly. Sample sizes were distributed based on probability proportional to size of the households in each Kebele. Census of all children in the selected Kebeles were conducted to set the sampling frame. Based on the sampling frame, cases and controls of acute respiratory infection in a child were identified using case definition of acute respiratory infection by interviewing their mothers. The mother of a child was interviewed about her child health history for assessment of cases and controls.

For exposure assessment, a sub sample of 110 kitchens and 66 were involved to determine the level of particulate matter ($PM_{2.5}$) and carbon monoxide pollution respectively from biomass fuel

using a monitoring equipment designed by the University of California, Berkeley Particle Monitor (UCB-PM) and HOBO CO data logger, respectively. Data were managed and analyzed using Epi Info and SPSS version 21. Exposure data were managed using UCB Monitor Manager software (Version 2.1.3) and BoxCar Pro software (Version 4.3) software. Descriptive statistics, Odds ratio, Chi-squired tests, Unconditional logistic regression, Linear regression, ANOVA, Pearson's correlation coefficient and Eta-test were employed.

Results: The study was conducted with the response rate of 99.65%. The mean age of the children was 24.15 (SD=14.98) months, while the age group between 12-23 months was accounted to 330 (28.86%). More than three-fourth of children lived in households that used mainly polluting fuel for cooking, biomass fuel 1001 (87.5%), while the rest only 143 (12.5%) of the households used mixed type of fuel energy, such as biomass, electricity, biogas and liquefied petroleum gas. About 712 (62.23%) of households had a kitchen separated from the main house, while 351 (30.68%) of the households had kitchen inside the living house. About 417 (58.5%) of the kitchen had no chimney, 666 (93.54%) didn't open windows during the cooking time.

The prevalence of acute respiratory infection in under-five children were 10.1% (95% CI 9.5, 10.8). Biomass fuel users for cooking (AOR=2.08, 95% CI 1.03-4.22), poorly ventilated houses (AOR=4.31, 95% CI 2.60-7.15), less than 2 years of child birth interval (AOR=1.40, 95% CI 1.02-1.91), large family size, (AOR=1.85, 95% CI 1.30-2.61), petty trade job of mother (AOR=0.50, 95% CI 0.31-0.81) were significant risk factors of acute respiratory infection in under five children.

A 24 hour Geometric mean concentration of $PM_{2.5}$ in all monitored households were 413.27 $\mu g/m^3$. The arithmetic mean 772.03 $\mu g/m^3$ (837.39) with 95% CI 613.04, 931.01. The 24 hour measurement of mean concentration of carbon monoxide in all monitored households were 14.26 mg/m^3 (SD=10.06). Type of fuel use, type of stoves (improved/traditional) and duration of time spent in cooking had significant differences on the level of particulate matter and Carbon monoxide.

Conclusions: The prevalence of acute respiratory infection is still a public health concern given the high level of household air pollution. Biomass fuel sources and poor house ventilation had a significant association on acquiring of acute respiratory infection. Mother's unemployment, higher family size, child birth interval of less than 2 years, biomass fuel use for cooking, living a poor

ventilated house and carrying child while cooking were risk factors of acute respiratory infection among children. The geometric mean concentration of particulate matter and carbon monoxide were much more exceeded the World Health Organization Air Quality Guideline values.

Recommendations: Promotion and distribution of improved cooking stoves, introducing better house design, promote a separate kitchen, to incorporate a sufficient number of windows and rooms in the house are sustainable solutions. Health education and promotion on the preventive measures of acute respiratory infection, the risk of biomass fuel combustion and engaging or carry child in the back while cooking and the importance of house ventilation should be delivered. Sustainable urban electrification (clean energy supply) is highly recommended solution to solve the cooking fuel related health problems.

Key words: Household air pollution, Cooking fuels, Ventilation, health effect Acute respiratory infection, Particulate Matter, Carbon monoxide

1. INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Around half of the world's population, relies on biomass fuels such as wood, animal dung, and crop residues. The majority of these households are located in poor rural communities and burn such solid fuels in inefficient devices, often in kitchens that are poorly ventilated, resulting in very high exposures to multiple toxic products of incomplete combustion (1-4).

Globally, air pollution is the largest single environmental health risk (5), linked to illness and early death and is the sixth leading risk factor globally, and household air pollution is the eighth leading risk factor (6). Nearly 95% of the world's population live in areas where fine particle levels exceed global air quality guideline. Almost 60% live in areas where fine particulate matter exceeds even the least stringent World Health Organization (WHO) interim air quality target of 35 $\mu g/m^3$ (7). According to World health organization in 2016 report, 3.8 million deaths are attributed to household air pollution annually, and 7.7% of the global mortality (8). People in developing countries are commonly exposed to very high levels of pollution for 3–7 hours daily over many years (9, 10). Household Air Pollution (HAP) from biomass cooking fuels is a major cause of morbidity and mortality in low-income settings worldwide (11). Nearly 80% of the population of sub-Saharan Africa use biomass fuels for cooking (12, 13).

When cooking households, incomplete combustion of biomass fuels releases a complex mixture of particulate matter (PM), carbon monoxide (CO), polycyclic aromatic hydrocarbons, and other toxins into the household environment (14). The most important compounds in household air environments include Suspended Particulate Matter, Carbon monoxide, SO2, NOx, and carcinogenic aromatic hydrocarbon, volatile organic compounds and bio-aerosols (15). Concentrations of combustion products household air can be substantially higher than those outdoors when heating and cooking appliances are used. This is particularly true in developing countries where stoves are used with imperfect kitchen and stove designs. There can be significant and widespread household exposures to many of the classical air pollutants, specifically, particulate matter and carbon monoxide, in developing countries. A particular issue for developing countries is exposure to emissions from cooking and heating which may produce the highest air pollution exposures to many pollutants (2).

Children, women and elders spend a large of their time households, which makes household spaces important microenvironments when addressing risks from air pollution. Most of a person's daily exposure to many air pollutants comes through inhalation of polluted air in the household, because of the amount of time spent in the house and presence of higher air pollution levels in the house. Household concentrations of air pollutants are influenced by outdoor levels, household sources, the rate of exchange between household and outdoor air, and the characteristics and furnishings of buildings. Household concentrations of air pollutants are subject to geographical, seasonal and diurnal variations (16).

Household air pollution is a major public health threat in developing countries requiring greatly increased efforts in the areas of research and policy-making. Conducting researches on household air pollution and its health effects is very important. A more systematic approach to the development and evaluation of interventions is desirable, with clearer recognition of the interrelationships between respiratory illness and polluting fuels.

1.2. STATEMENT OF THE PROBLEM

The evidence is clear that air pollution has a devastating impact on children's health (17). Air pollution is one of the biggest environmental health challenges confronting humanity. It is an invisible murderer and foremost cause of some of the most common human health crisis (18). Globally, 93% of all children live in environments with air pollution levels above the WHO guidelines (17). Acute respiratory infections in children and chronic obstructive pulmonary disease in women are the main problems in developing countries which are associated with household biomass smoke (4). The use of solid fuels for cooking is a major environmental and public health challenge in developing countries, indoor cooking and use of solid fuel in household increase the risk of acute respiratory infection (ARI), low birth weight, cesarean delivery, and pregnancy complication (19) and HAP exposure is a major health risk that requires well-tested interventions (20). In 2016, 41% of the world's population was exposed to HAP from cooking with polluting fuels and technologies. The use of polluting fuels and technologies for cooking is almost exclusively a problem in low and middle income countries, as 83% of the population in the African Region, 59% in the South-East Asia Region and 42% in the Western Pacific Region rely primarily on polluting cooking fuels (17). HAP was responsible for 3.8 million premature deaths in 2016, including over 400 000 deaths of children under 5 years (17).

According to the Ethiopian demographic and health survey (EDHS, 2016) report, ARI is among the leading causes of child morbidity and mortality in Ethiopia next to fever and diarrhae. Pneumonia is the most serious outcome of ARI in young children. One in every 17 Ethiopian children die before the first birthday and one in every 11children dies before the fifth birthday due to different causes. According to the EDHS report, 7% of under-five children in Ethiopia have showed symptoms of ARI (21, 22).

The problem of low birth is another concern of the countries problem, the EDHS 2016 result indicating the proportion of children born underweight was accounted to 20.1% in urban residence of Ethiopia (22), is an indication of the problem currently existed (23). High pollutant cooking fuels resulted in higher odds of having low birth weight (LBW) child compared to use of electricity/gas in Bangladesh (24), Pakistan (25), in Nepal linked with small size at birth (26).

Ethiopia is a country, which is found in sub-Saharan Africa. The countries 84% of the population is found in rural areas, which very limited access to electric power for heating houses, cooking foods and lighting. Biomass fuel is exclusively used for cooking foods and heating houses. When the biomass fuels get burned in sub optimal conditions, these fuels emit high concentrations of health damaging pollutants, including particulate matter and carbon monoxide. Culturally, in Ethiopia females especially women are expected to cook foods, care for children and serving their families. Women carry their child in their back while cooking and children spend hours close to cooking fire with their mother, and hence have high exposures to these health damaging pollutants (19). Hence, the exposure to various pollutants including biomass fuel emission, children are prone to respiratory health problem and other diseases.

The housing design and structures of houses in Ethiopia are not designed to exhaust household air pollutants, hence, incomplete combustion of these fuels and poor ventilation result in high household concentrations of health-damaging pollutants and hence, women and young children are exposed to high level of household air pollution every day in which its magnitude yet not determined so far.

Evaluating and managing the health risks of household air pollution in developing countries is complex. In most studies', exposure-response were not considered due to resource intensiveness and methodological complexity. This problem is more serious in poor countries like Ethiopia as compared to developed one. Most studies focused on the stove type, fuel type and amount of emissions' and therefore determination of estimation of burden of these household air pollutants were mostly from the indirect estimations.

Another study was conducted to measure levels of household NO_2 concentration as a proxy indicator of air pollution in homes with under-five children in rural Ethiopia (Butajira area). Wood, crop residues and animal dung were the main household fuels. The level of NO_2 was more than double the currently proposed annual mean of WHO air quality guideline. Highland households had significantly higher household NO_2 concentration. This study demonstrates high levels of household NO_2 in rural homes of Ethiopia (27).

Many of thousands of housing types in Ethiopia are constructed in a local and in a traditional manner, which are often unable to facilitate ventilation or providing very limited ventilation while mothers or the cook are cooking or heating their house. As a result, cooking, the local and traditional stove generates most household emissions; there is a confluence of emissions, people, and time in places. Unfortunately, regular monitoring and measurements of these household air pollutants are not being done in Ethiopia.

A wide variety of pollutants, exposure levels and possible health effects must be considered, along with differences in cultural habits, lifestyles and climate. In addition, some people – such as children, pregnant women and the elderly may be more vulnerable than others may. With this opinion, this reasonable project aims to provide a scientific basis for assessing the risks to human health linked to household air quality focus on vulnerable groups of population such as children, and mothers.

Previous studies were, dominantly cross-sectional study designs, main pollutants were not measured and characterized, and they are measured for short period like, only in mealtime, cooking time only, 15 minutes to hour duration, most studies were limited in Addis Ababa city and focused on women respiratory illness only. Moreover, in Ethiopia, the links between household air pollution and health outcomes were not sufficiently addressed yet especially those related to acute respiratory infections and therefore this work will attempt to address a part of this national burden and gaps.

1.3. RATIONALE AND SIGNIFICANCE OF THE STUDY

Household air quality is the most determinants of human health than others, and hence conducting this basic determinant is worth big to the health of societies especially for those who are more vulnerable groups of the family and for policy makers. Mothers, elders, children and sick peoples are most vulnerable group of the family. Recently, acute and chronic level of diseases related to household air quality are an emerging health problems, which has to be addressed early. However, addressing or assessing the issue is not a simple task that can be done through short duration of time and with scarcity of resources.

Carbon monoxide and particulate matters are most significantly affecting the health of inhabitants, and these are the products of incomplete combustion of biomass fuels. Incomplete combustion is a common practice in most household due to inappropriate housing structure and poorly designed stoves. Following this problem, stoves emit high concentration of pollutants routinely throughout cooking. But the concentration of these pollutants (particulate matter and carbon monoxide) in developing countries especially in sub Saharan countries are not sufficiently addressed. Limited number of studies have investigated the relationship between household pollutants and health outcomes. Studies conducted in developed countries or other less developed countries might not be used as a proxy to estimate ours, because of differences in environmental, socioeconomic and sociocultural contexts. Estimating the exposures as well as the related health outcomes directly from the beneficiary is much worth for appropriate interventions policy issues.

Taking into account of these considerations, this research aimed to describe household air pollution and the contribution of household air pollution on health outcomes especially on acute respiratory infections among under-five children. This study document will help policy makers, decision makers and local governors in order to reconsider the existing policies following the result of the study for the benefit of the community and the people at large.

2. LITERATURE REVIEW

2.1. OVERVIEW OF HOUSEHOLD AIR POLLUTION USING PROXY DETERMINANTS

About half of the world's population relies on biomass fuels as the primary domestic energy source (6). Household air pollution is responsible for an estimated of 4–6% of the burden of disease (28) in developing countries. This health hazard primarily affects women and young children, as they spend much time in close proximity to the fire (29-31). Globally, household solid fuel combustion is responsible for as much as half of all black carbon emissions from human sources and significant amounts of total carbon monoxide and volatile organic chemical emissions (32, 33).

According to WHO report in 2018, the sources and levels of air pollutants in developing countries are significantly different from those in the developed world (17). In developing countries, population explosion along with widespread industrialization coupled with urbanization has resulted in dense urban centers with poor air quality. The use of biomass fuels in rural areas subjects the population to high household air pollution. Due to incomplete combustion, the use of biomass fuels in traditional stoves produces high levels of household air pollutants. This smoke contains a range of health deteriorating substances that, at varying concentrations, can pose a serious threat to human health (34).

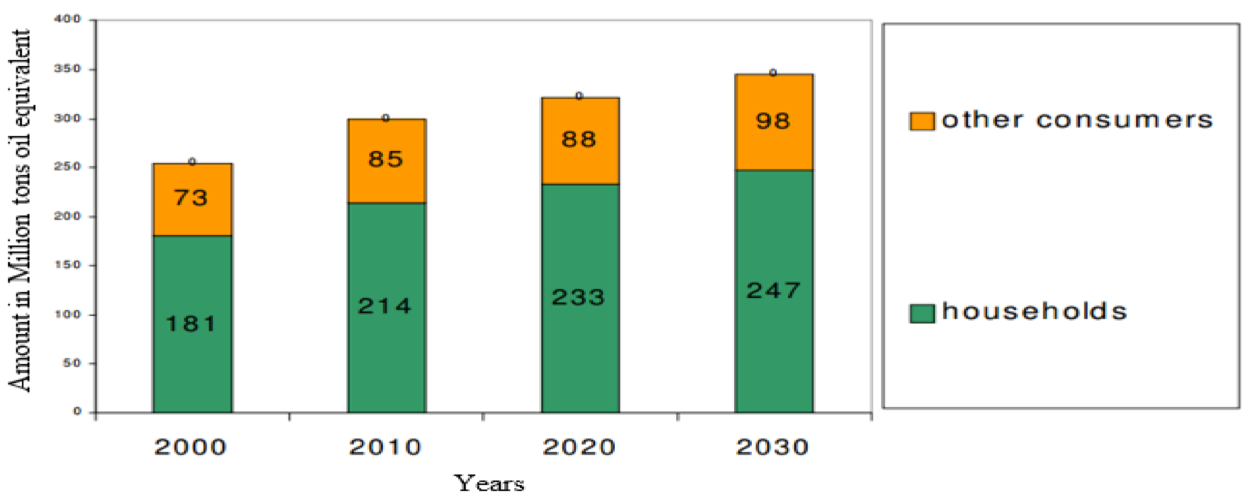


Figure 1. Projected biomass fuel consumption in Africa, in years with million tons oil equivalent.

Approximately half of the world's population and up to 90% of rural households in developing countries still rely on solid fuels as their primary energy source for participating women using the traditional open fire (35). Recent evidences showed that exposure to household air pollution, and specifically fine particulate matter, may adversely affect birth weight (36).

A study conducted in India to assess the status of air pollution showed that environmental and occupational risk factors contribute to nearly 40% of the national burden of disease in India, with air pollution of the household and outdoor environment ranking amongst leading risk factors. In India it is also recognized that, the health burden from air pollution exposures that primarily occur in the rural households due to the incomplete combustion of solid fuels in households is major contributor to the global burden of disease (37, 38).

According to the WHO report, in Pakistan HAP due to solid fuel use is responsible for 4.6% of national burden of disease (39). Past burden of disease estimates for HAP related to solid cooking fuel combustion have relied on categorical exposure indicators such as use of solid versus clean fuels (12).

According to a study by Smith et al., in 2004, 80% of the population of sub-Saharan Africa use biomass fuel and coal for cooking and heating purposes (12). In most developing countries, biomass is burned in traditional open fires leading to high concentrations of multiple pollutants (12, 40).

2.2. LEVELS OF HOUSEHOLD AIR POLLUTION

i) Level of particulate matter ($PM_{2.5}$)

Fine particulate matter ($PM_{2.5}$) is a general term for all small particles found in air measuring equal to or less than 2.5μm in aerodynamic diameter. This size has been shown to be a significant predictor of respiratory health (17, 41). It is a complex mixture whose constituents vary in size, shape, density, surface area, and chemical composition. The concentration and distribution of household air pollutant varies from time to time and from place to place, depending on the type of fuel, stove, and housing characteristics; and that significant temporal and spatial variations may occur within a house (42).

The level of PM (quantifications) is determined using two methods of measurement: area and personal, the latter being relevant for compliance assessment. Personal pollutant concentrations are measured by directly placing the sampler on the person, while in case of area measurement; samplers are placed in fixed area. Both of the measurement are subjected to variability due to temporal and spatial gradients around a cook stove (33, 43).

A quantified exposure to respirable particulate matter from biomass-fuel combustion in rural homes from four districts of biomass-using households in Tamil Nadu, India on personal exposures during cooking were reported with a concentrations ranged from 500 to 2,000 $\mu g/m^3$, and average 24 hour exposures who were not involved in cooking ranged from 90 ± 21 $\mu g/m^3$, but for those who cooked were 231 ± 109 $\mu g/m^3$ (38).

Exploratory study in Palwal District, Haryana, India, provides preliminary data on the kitchen area concentrations and kitchen personal concentrations assessed during cooking events were emitted a very high concentration of pollutant, with respective mean $PM_{2.5}$ concentrations of 468 and 718$\mu g/m^3$; in addition, twenty-four hour outdoor concentrations was an average of 400$\mu g/m^3$ (44).

Monitoring of 24-hour household concentrations of $PM_{2.5}$, in 617 rural households India on a cross-sectional basis between November 2004 and March 2005 has revealed that the mean 24-hour concentration of $PM_{2.5}$ in solid cook-fuel using households ranged from 163 $\mu g/m^3$ (95% CI: 143,183; median 106) in the living area to 609 $\mu g/m^3$ (95% CI: 547,671; median: 472) in the kitchen area. Extrapolation of the household results by state to all solid cook-fuel using households in India, covered by 2005, resulted in a modeled estimate of 450 μg/m^3 and 113 μg/m^3, for national average 24 hour $PM_{2.5}$ concentrations in the kitchen and living areas respectively (45).

Independent and multidisciplinary review of China's National Improved Stove Program carried out since the 1980s. As part of a 3500-household survey, a subsample of 396 rural households were monitored for particulate matter < PM_4 in kitchens and living rooms over 24 hours, of which 159 were measured in both summer and winter. The results of this household air quality (HAQ) component indicate that for nearly all household stove or fuel groupings, PM_4 levels were higher than and sometimes more than twice as high as the national PM_{10} standard for household air (150 μg/m^3) (46). A study in Italy showed that the mean levels of pollutants were significantly higher in winter than in summer, regardless of the area (urban and rural) (47).

Stationary monitoring in the China study result indicates that rural kitchen PM_{10} levels are three times higher than those in urban kitchens during cooking. PM_{10} was 6.1 times higher during cooking periods than during non-cooking periods for rural kitchens. Personal $PM_{2.5}$ levels for rural cooks were 2.8–3.6 times higher than for all other participant categories. The highest $PM_{2.5}$ exposures occurred during cooking periods for urban and rural cooks. However, rural cooks had 5.4 times higher $PM_{2.5}$ levels during cooking than did urban cooks. Rural cooks spent 2.5 times more hours per day cooking than did their urban counterparts (48).

A study to estimate the exposure of $PM_{2.5}$ for 1266 children in Gambia revealed that, children were exposed to the amount of $PM_{2.5} =$135 ± 38 μg/m^3; 25% of children had exposures of 151 μg/m^3 or higher. The estimated exposure was highest among children who lived in homes that used firewood as their main fuel (144μg/m^3) compared to those who used charcoal (85μg/m^3) and concluded that children in Gambia have relatively high $PM_{2.5}$ exposure (49).

A recent study conducted in Ethiopia to assess the magnitude of household air pollution from household fuel use in slum neighborhoods of Addis Ababa (50, 51), showed that, the concentration of fine particulate matter ($PM_{2.5}$) in 59 households was measured and the result was: the geometric mean with standard deviation (SD) of 24-hour household $PM_{2.5}$ concentration is approximately 818±3.61μg/m^3. The highest 24-hour geometric mean and SD of $PM_{2.5}$concentration observed were 1134±3.36μg/m^3, 637±4.44μg/m^3, and 335±2.51μg/m^3, in households using predominantly solid fuel, kerosene, and clean fuel respectively and it was concluded that household air pollution is a major environmental and health hazard from home using biomass fuel in Addis Ababa and the use of clean fuels and efficient cooking stoves had been recommended (50, 51).

The research examines PM levels in the homes of women living in Shero-Meda sub city of Addis Ababa, Ethiopia revealed that the 24-hour particulate matter levels in the kitchens ranged from 135 µg/m^3 to 12,737 µg/m^3 with a Geometric mean (SD) 793.38 (1580) µg/m^3. All households exceeded the United States Environmental Protection Agency standard of 35 µg/m^3 (52).

World Health Organization has developed household air quality guidelines values for household fuel combustions for different air pollutants mainly based on the significance level of health risk factors. Therefore, the guideline recommendation is $PM_{2.5}$ for 24-hour Geometric mean level in houses should not exceed 25 µg/m^3 and PM_{10} was 50 (µg/m^3) (53). $PM_{2.5}$, WHO Interim Target-1 (IT-1) is 75µg/m^3, WHO Interim Target-2 (IT-2) is 50 µg/m^3 and WHO Interim Target-3 (IT-3) is 37.5 µg/m^3 (2, 54)

ii) Level of Carbon monoxide

Carbon monoxide is a colorless, non-irritant, odorless and tasteless toxic gas. It is produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, coal, natural gas and kerosene. Its molecular weight is 28.01 g/mol, melting point -205.1 ºC, boiling point (at 760 mmHg) –191.5 ºC, density 1.250 kg/m^3 at 0 ºC and 1 atm and 1.145 kg/m^3 at 25 ºC and 1 atm. Its solubility in water at 1 atm is 3.54 ml/100 ml at 0 ºC, 2.14 ml/100 ml at 25 ºC and 1.83 ml/100 ml at 37 ºC (53).

World Health Organization has developed household air quality guidelines values for household fuel combustions for different air pollutants mainly based on the significance level of health risk factors. Therefore, the guideline recommendation a 24 hour mean level of CO was 7 (mg/m^3) (53).

Exploratory study in Palwal District, Haryana, India, provides preliminary data on a 24 hour CO concentrations measurements for the kitchen area and kitchen personal CO concentrations was ranged between 0.82 and 5.27 ppm respectively (44).

A study in The Gambia to measure the concentrations of CO from children of under 5 years of age using small, passive, color stain diffusion tubes, with multiple CO measurements to measure day-to-day exposure variability showed that the mean measured CO exposure for 1181 children was 1.04±1.46 ppm, indicating that the Gambian children in this study on average have a relatively low

CO exposure. However, 25% of children had exposures of 1.3 ppm or higher. CO exposure was higher during the rainy months (1.33±1.62 ppm). Burning insect coils, using charcoal, and measurement done in the rainy season were associated with higher exposure (16). Similarly, $PM_{2.5}$ exposure was estimated for 1,266 children in The Gambia by applying the cookhouse $PM_{2.5}$-CO relationship to the child's CO exposure. Using this indirect method, mean $PM_{2.5}$ exposure for all subjects was 135 ± 38 μg/m^3; 25% of children had exposures of 151 μg/m^3 or higher. Indirectly-estimated exposure was highest among children who lived in homes that used firewood as their main fuel (144 μg/m^3) compared to those who used charcoal (85 μg/m^3) (49).

The research examines CO levels in the homes of women living in Shero-Meda sub city of Addis Ababa, Ethiopia revealed that the 8-hour carbon monoxide averages among households ranged between 0.66 ppm and 69 ppm with a mean (SD) 16.08 (18.81) ppm. Twenty-six households exceeded the United States Environmental Protection Agency 8-hour average of 9 ppm (52).

A cross-sectional study was conducted in Bonga, Ethiopia revealed that, the average amount of $PM_{2.5}$ in 12 traditional household stoves in 24 hour duration was a mean and standard deviation of 25.31 (21.87) mg/m^3 (55).

iii) Level of Nitrogen dioxide (NO_2)

A 24 hour level of NO_2 in households was studied in Butajira, Ethiopia, which used biomass fuel for cooking was measured to 97μg/m^3(27). This result was twice of the WHO guideline value for NO_2 concentrations recommendation in households was set to 40 μg/m^3 for annual mean (2, 53).

2.3. DETERMINANT FACTORS OF HOUSEHOLD AIR POLLUTANTS

The amount and relative proportion of air pollutants generated by solid fuel combustion are dependent on a number of factors, including fuel type and its moisture content, household ventilation factor, the practice of the people using the stoves, and the stove technology (56, 57). Several studies conducted in other parts of the world have investigated exposures to household air pollution from biomass fuels with the finding that exposure patterns differed by sex, location in the home, and activity patterns (e.g., cooking vs. non-cooking) (38, 58, 59).

i. Kitchen characteristics, type of stove and biomass fuel use

Housing characteristics were determined to indicate ventilation that may affect carbon monoxide and $PM_{2.5}$ (60). A study to assess the relationship of biomass smoke, particulate matter, carbon monoxide and kitchen characteristics in Burkina Faso indicated that, the majority of households used outdoor kitchens and outdoor stoves. Even though many of the households owned and used more than one type of stove, the traditional three-stone stove was popular one. The mean size of household kitchens was 7.0 m^2 (95 %CI 6.3–7.7 m^2). Most household kitchens had windows (n =51, 96.2 %) with mean window areas of 0.32 m^2 (0.19–1.1 m^2). The mean door area of household kitchens was 1.7 m^2 (95 %CI 1.3–2.1 m^2). Windows and doors were generally open most of the day. None of the kitchens or stoves had chimneys. The placement of outdoor kitchens varied, with some located next to a wall, in a partially enclosed area or as a free-standing structure in the courtyard. The mean number of meals cooked on the day of PM and CO monitoring was 1.5 (95 % CI 1.4–1.6) and the mean time spent in the kitchen on the day of monitoring was 2.4 hour (95%CI2.2–2.5 h). The mean PM and CO (area and personal) concentrations by kitchen characteristics recorded mean 24-h PM_{10} concentrations among the 148 households sampled were very high (2537 μg/m^3, 95%CI, 799–3,274 μg/m^3) but were within the range reported in other studies (61).

Burning biomass in traditional stoves, open-fire three-stone "stoves", or other stoves of low efficiency, and often with little ventilation emits smoke containing large quantities of harmful pollutants. Fuel type, type and location of the kitchen, and the time spent near the kitchen while cooking were the most important determinants of exposure across rural households of Southern India among other parameters examined, including stove type, cooking duration, and smoke from neighborhood cooking (38).

Fuel type, kitchen type, ventilation, geographical location and cooking duration were found to be significant predictors of $PM_{2.5}$ concentrations in the household. Extrapolation of the household results by state to all solid cook-fuel using households in India, covered by 2005, resulted in a modeled estimate of 450 μg/m^3 and 113 μg/m^3, for national average 24 hour $PM_{2.5}$ concentrations in the kitchen and living areas respectively (45).

The high prevalence of solid cook fuel use (such as biomass and coal) for household energy needs in poor communities of developing countries (1) has been known to result in exposures to multiple toxic products of incomplete combustion. In households, solid fuels are often burned in inefficient, poorly vented combustion devices (open fires, traditional stoves). The incomplete combustion of these solid fuels results in much of the fuel energy being emitted as potentially toxic pollutants, including particles of varying sizes, carbon monoxide, nitrogen dioxide, volatile and semi-volatile organic compounds (33).

A study carried out in 30 households in rural Guatemala to test three different types of cook-stoves, a 24-hour $PM_{3.5}$ concentrations were compared over 8 months for three fuel/cookstove conditions: a traditional open fire cookstove, an improved cook stove, and a liquefied petroleum gas (LPG) stove/open fire combination. 24-hour geometric mean $PM_{3.5}$ concentrations were 1560μg/m^3, 280μg/m^3, and 850μg/m^3 for the open fire, an improved cookstove, and LPG/open fire combination, respectively. The improved cookstove showed an 85% reduction in $PM_{3.5}$ concentrations as compared to the open fire ($p<0.0001$). Season did not affect pollutant concentrations (62).

The impact of an improved wood burning stove (Patsari) in reducing personal exposures and household concentrations of particulate matter and carbon monoxide was evaluated in 60 homes in a rural community of Michoacan, Mexico. Average PM. Introduction 2.5 24-h personal exposure was 0.29 mg/m^3 and mean 48-h kitchen concentration was 1.269 mg/m^3 (35).

Particulate pollution has emerged as a serious environmental health concern in Pakistan. The use of biomass fuels in traditional stoves produces high levels of household air pollutants. A large variation was recorded in the mass concentration of particulate matter during cooking with concentrations in the range 4000–8555 μg/m^3. Cooking, cleaning and smoking were identified as principal contributors to the high household levels of particulate matter. The study showed considerably high concentrations of particulate matter, particularly in kitchens using biomass fuels, as compared to living areas. Generally, the study observed a wide variation in concentration of particulate matter among different kitchens and even within the same kitchen during different episodes of cooking. The variation primarily depended on the quality (dryness) of biomass fuel used, duration of cooking, degree of incomplete combustion and ventilation (63).

ii. Socioeconomic and demographic determinants

A study in India among solid fuel users, the mean 24-h average exposures were the highest for women cooks and were significantly different from men and children. Among women, exposures were the highest in the age group of 15–40 years (most likely to be involved in cooking or helping in cooking), while among men, exposures were highest in the age group of 65–80 years (most likely to be households) (64).

Income and education can also be expected to affect family size and type of housing that in turn affect fuel quantities or the number of rooms and/or location of the kitchen. Access to cleaner fuels may also be independently influenced by the prevalent national and regional energy market structures, which in turn would be linked to the gross domestic product of individual countries. Countries with a low gross domestic product per capital may experience greater gender inequities in terms of income, education, access to health care, social position and socio-cultural preferences, all of which could potentially influence the exposures of vulnerable groups, such as women and children (13).

As expected, the econometric results indicate that fuel choice significantly affects household pollution levels: natural gas and kerosene are significantly cleaner than biomass fuels (65). The result indicated that great geographic variation, even for households in the same per capita income group. This variation reflects local differences in fuel use and, more significantly, construction practices that affect ventilation (65).

iii. Housing conditions and home practice

House ventilation is the critical for home comfort. Proper ventilation improves the life and quality of inhabitants. Proper ventilation prevents air pollutants from affecting the health of you and your family. Ventilation can be either in a natural or artificial way, however in most developing nations the natural ventilation is mostly applicable, but because of lack of awareness of the benefit of windows and ventilation, most of them didn’t use it properly (66). A study was conducted households of Dhaka and Narayanganj, Bangladesh with a particular focus on fuel use, cooking locations, structural materials, ventilation practices, and other potential determinants of exposure to indoor air pollution (IAP). PM_{10} concentrations in the kitchen were monitored for a 24-h period during December, 2003–February, 2004, and the concentrations of 300 μg/m^3 or greater are common in the selected households, implying widespread exposure to a serious health hazard. Fuel choices and a large set of variables that describe household cooking and ventilation practices, structure characteristics and building materials were found to be factors associated with high level of PM_{10} concentrations (65).

Housing characteristics were determined to indicate ventilation that may affect carbon monoxide and $PM_{2.5}$ in Honduran communities and it showed that designing kitchens with proper ventilation structures could lead to improved household environments, especially important in areas where biomass will continue to be the preferred and necessary cooking fuel for some time (60).

In a study to assess the association of kitchen characteristics with measured PM_{10} and CO levels and the relationship of PM_{10} with CO concentrations, across different kitchen characteristics in households in Nouna, Burkina Faso was shown that 24-hour concentrations of PM_{10} (area) were measured with portable monitors and CO (area and personal) estimated using color dosimeter tubes. Most households used both wood and charcoal burned in three-stone and charcoal stoves. Mean outdoor kitchen PM_{10} levels were relatively high (774μg/m^3), but lower than the household concentrations. Strong area PM_{10} and area CO correlations were found with household kitchens and household stove use. Weak correlations between area PM_{10} and personal CO levels were observed with three-stone and improved stoves (61).

A study in rural southwestern Ethiopian communities has documented the biomass fuel-related problems. These included the conditions that produced exposure such as no separate kitchen and lack of windows and elevated particulate matter concentrations (67).

iv. Cooking practice

A study was conducted in Ghana to examine cooking practices and 24-h personal and kitchen area exposures to fine particulate matter ($PM_{2.5}$) and black carbon in cooks that using biomass fuel. Thus, researchers administered a detailed survey to 421 households. In a sub-sample of 36 households, researchers collected 24-h integrated $PM_{2.5}$ samples (personal and kitchen area); in addition, the primary cook was monitored for real-time $PM_{2.5}$. The majority of households cooked outdoors (55%), used biomass (wood or charcoal) as their primary fuel (99%), and cooked on traditional fires (77%). In the sub-sample of 29 households with complete, valid exposure monitoring data, the 24-h integrated concentrations of $PM_{2.5}$ were substantially higher in the kitchen sample (mean 446.8 $\mu g/m^3$) than in the personal air sample (mean 128.5$\mu g/m^3$). Black carbon concentrations followed the same pattern such that concentrations were higher in the kitchen sample (14.5$\mu g/m^3$) than in the personal air sample (8.8$\mu g/m^3$) (68).

v. Environmental factors and behavioral patterns

The Gambian study conducted to show the behavioral patterns and individual-level characteristics (e.g., age, socioeconomic status, time spent in the cooking area) and household-level characteristics (e.g., fuel/stove type, cookhouse ventilation, use of biomass for heating, location of the kitchen in relation to other rooms) indicated that all contributed to variations in personal exposures, both within and between individuals. In addition, these characteristics and thus the magnitude of exposures have varied across geographical regions (countries, cities, villages, and neighborhoods), time, and season of the year (16).

A study in the rural northern Ethiopia indicated that 80% of households were using biomass fuel for cooking; study only 13% of women thought that, smoke exposures were of concern (69).

2.4. ARI and HOUSEHOLD AIR POLLUTIONS

Household air pollution is an important risk factor for acute lower respiratory tract infections (ALRTI) in developing countries. Household air pollution caused by using cooking fuel other than LPG and socio-economic factors are significantly associated with ALRTI (70) .

Risk factors that increase the incidence and severity of lower respiratory infection in developing countries include large family size, low birth weight, lack of breast-feeding lateness in the birth order, crowding, malnutrition, vitamin A deficiency, pollution, and young age, low paternal education, young maternal age, attendance at day-care center, weight-for-age, non-milk supplements and history of previous pneumonia or wheezing. Acute respiratory tract infections are the most common illnesses in childhood, comprising as many as 50% of all illnesses in children less than 5 years old and 30% in children aged 5–12 years. The WHO-comparative risk assessment exercise in 2002 used estimates of relative risk obtained from meta-analyses of epidemiological studies for only three disease end-points for which there is strong evidence of an association with use of solid fuels, namely, ALRTI in children aged <5 years, Chronic obstructive pulmonary disease (COPD), and lung cancer (only for use of coal) (12).

More recently, systematic reviews with meta-analyses of the available epidemiological evidence have been completed which revealed that household air pollutants caused ALRTI in children (71, 72), low birth weight (72), COPD in women (73), and lung cancer (74).

A case control study to determine the relationship of household air pollution with ALRTI in children under-five years of age in India revealed that, of those with ALRTI, 24.8% had pneumonia, 45.5% had severe pneumonia and 29.7% had very severe disease. Exposure to passive smoking was not associated with ALRTI. Cooking fuel other than LPG was significantly associated with ALRTI (OR 26.3, 95% CI 10.5–65.7). On logistic regression analysis of multiple risk factors, cooking fuel other than LPG emerged as a significant risk factor for developing ALRTI (adjusted OR 4.73, 95% CI 1.67–13.45) along with poor socio-economic status (adjusted OR 3.38, 95% CI 1.63–7.03) (70). An increasing number of studies pointing at effects of smoke on other lung diseases, mainly ARI and COPD (59, 75).

A cross-sectional study conducted to evaluate the association between use of biomass fuel and ARI episodes in children aged under five years in Pakistan revealed that, the incidence of ARI was higher in children living in houses where biomass fuel was used and who accompanied their mothers while cooking compared with children living in houses where fossil fuel was used and who did not accompany their mothers while cooking [rate ratio 2.6, 95% CI 1.5-4.5]. Compared with the latter group, the incidence of ARI was also higher in children living in houses where biomass fuel was used but who did not accompany their mothers during cooking (RR 1.5, 95% CI 1.2-1.9) (76).

A study conducted to assess the prevalence of acute respiratory infections in women and children in Western Sierra Leone due to smoke from wood and charcoal Stoves revealed that ARI prevalence revealed 32% and 24% for women, 64% and 44% for children in homes with wood and charcoal stoves, respectively. After adjusting for potential confounders for each group, the odds ratio of having suffered from ARI was similar for women, but remained large for children in homes with wood stoves relative to charcoal stoves (OR = 1.14, 95%CI: 0.71–1.82) and (OR = 2.03, 95%CI: 1.31–3.13), respectively (77).

In Kenya, a study revealed that air pollutants from biomass combustion showed significant health effect in rural areas; and in particular, acute respiratory infection increased with increasing exposure to particulates with a mass median aerodynamic diameter less than 10μm (78).

Due to the lack of measurements of pollutants other than $PM_{2.5}$ and CO, much of the emphasis for health effects has been on $PM_{2.5}$ because it is thought to be the most relevant size fraction for health (75, 79).

There is increasing evidence that biomass smoke is a risk factor for pneumonia, the leading cause of child death worldwide (16, 31). A study to assess the contribution of household fuel use and ARI in children in Gondar city of Ethiopia revealed that, 54.7% lived in households using biomass fuels from which 26.3% suffered from ARI during the 2 weeks preceding the survey interview. Children in households using wood, dung, or straw for cooking were 3.89 times more likely to have suffered from ARI as compared to children from households using LPG or electricity (OR = 3.89; 95% CI: 1.54, 28.25) (80).

A recently conducted researches showed that acute upper respiratory infection increased with annual growth rate 47.18% from incidents 4539 (2003) to 212590 (2017) in Ethiopia. Pneumonia is being increased by annual growth rate about 24.89%. Also, there are several other or unspecified diseases of the respiratory system are currently being recorded at health care centers (81).

2.5. MECHANISM OF ARI VERSUS HOUSEHOLD AIR POLLUTION

Particulate matter: In situations in which individual exposure to specific agents, particle size of air contaminant must be considered. Particulate matters have different size but from the health point of view, <10 µm, <2.5µm and <0.1µm aerodynamic diameter are very important to recognize how the mechanism of causing disease to human being. Because of their settling velocities in air, particles >10–15µm in diameter do not penetrate beyond the nose and throat. Particles <10µm in size are deposited below the larynx. Particles~2.5–10µm (coarse-mode fraction) mostly deposit relatively high in the tracheobronchial tree. Although the total mass of an ambient sample is dominated by these larger respirable particles, the number of particles, and therefore the surface area on which potential toxic agents can deposit and be carried to the lower airways, is dominated by particles <2.5µm (fine-mode fraction). The smallest particles, those <0.1µm in size, represent the ultrafine fraction and make up the largest number of particles; they tend to remain in the airstream and deposit in the lung only on a random basis as they come into contact with the alveolar walls. If they do deposit, however, particles of this size range may penetrate into the circulation and be carried to extrapulmonary sites. Water-soluble gases are absorbed in the lining fluid of the upper and proximal airways and thus tend to produce irritative Broncho constrictive responses. In contrast, less water-soluble gases may penetrate to the bronchioles and alveoli in sufficient quantities to produce acute chemical pneumonitis that can be life-threatening causing acute (i.e. bronchial irritation, inflammation and increased reactivity), reduced mucociliary clearance, reduced macrophage response, and reduced local immunity, and fibrotic reaction. These effects have mainly involved production of an inflammatory response, exacerbation of existing airway disease (e.g. hyperreactivity) or impairment of pulmonary defense mechanisms. Inhaled PM may increase the production of antigen-specific immunoglobulins, alter airway reactivity to antigens or affect the ability of the lungs to handle bacteria, suggesting that exposure may result in enhanced susceptibility to microbial infection (4, 82).

Carbon monoxide: CO diffuses rapidly across alveolar, capillary and placental membranes. Approximately 80-90 % of the absorbed CO binds with hemoglobin to form carboxyhemoglobin (COHb), which is a specific biomarker of exposure in blood. During exposure to a fixed concentration of CO, the COHb concentration increases rapidly at the onset of exposure, starts to level off after 3 hours, and reaches a steady-state after 6-8 hours of exposure. It is a mechanism of binding with hemoglobin and myoglobin to produce carboxyhemoglobin, which reduces or prevents oxygen binding, transport, and tissue uptake that impairs the release of oxygen from hemoglobin. These are the main causes of tissue hypoxia produced by CO at low exposure levels. CO contributes to the formation of smog ground-level ozone, which can trigger serious respiratory problems (4, 82).

2.6. PRINCIPLES OF HOUSEHOLD AIR POLLUTION MEASUREMENT

The choice of exposure assessment method should be driven by the questions being asked. In some cases, exposure assessment is used to inform public health research, in other cases, exposure assessment is an important input to policy and/or planning decisions, such as when designing effective intervention programs and control strategies, or evaluating compliance with regulatory standards. Real-time measures of pollutant concentration can constitute a rich data set for assessing temporal variability. Time-integrated (continuous) sampling provides an average value over the time sampled. The length of the sampling time is a crucial consideration in assessing temporal variability for both approaches and will change depending on the purpose of sampling (e.g., whether to describe long-term or short-term exposure) and the site characteristics and behavior of the study population. Multiple-day measures allow assessment of variability of both cooking and non-cooking time exposures across an even larger sampling of cooking events and days (83). The main instruments and methods of measuring concentration (gravimetric, optical, and microbalance) and size distribution Scanning Mobility Particle Sizer, Electrical Low-Pressure Impactor and others. There are several instruments for measuring different characteristics of particulate matter. The most important measurements of particles are particle concentration and particle size. A particle size analyzer can determine the behavior of the particle in ambient air, while particle concentration measurements are important to standardize emission limits, which guarantee the standards of air quality. In concentration methods, the PM concentration can be in mass (m), number (N) and surface area (S). In the gravimetric method, the particle mass concentration is determined by weighing the filters before and after the sampling period. In the optical detection methods, aerosol particles are lit by a light beam and irradiate this light in all directions (scattering) (84).

In this study, particulate matter was measured in concentration technicques with optical methods of measuring particulate matter. These optical devices are measured the concentration of particulates with scattering of a beam of light occurs when the sample introduced through the inlet nozzle is irradiated with light and then the particles pass through the light. The scattered light is detected by the photo detector and its converted to electrical signals. The size of the electrical signals represents the particle count (85). The co-location of devices was measured by gravimetric devices using filter weight techniques.

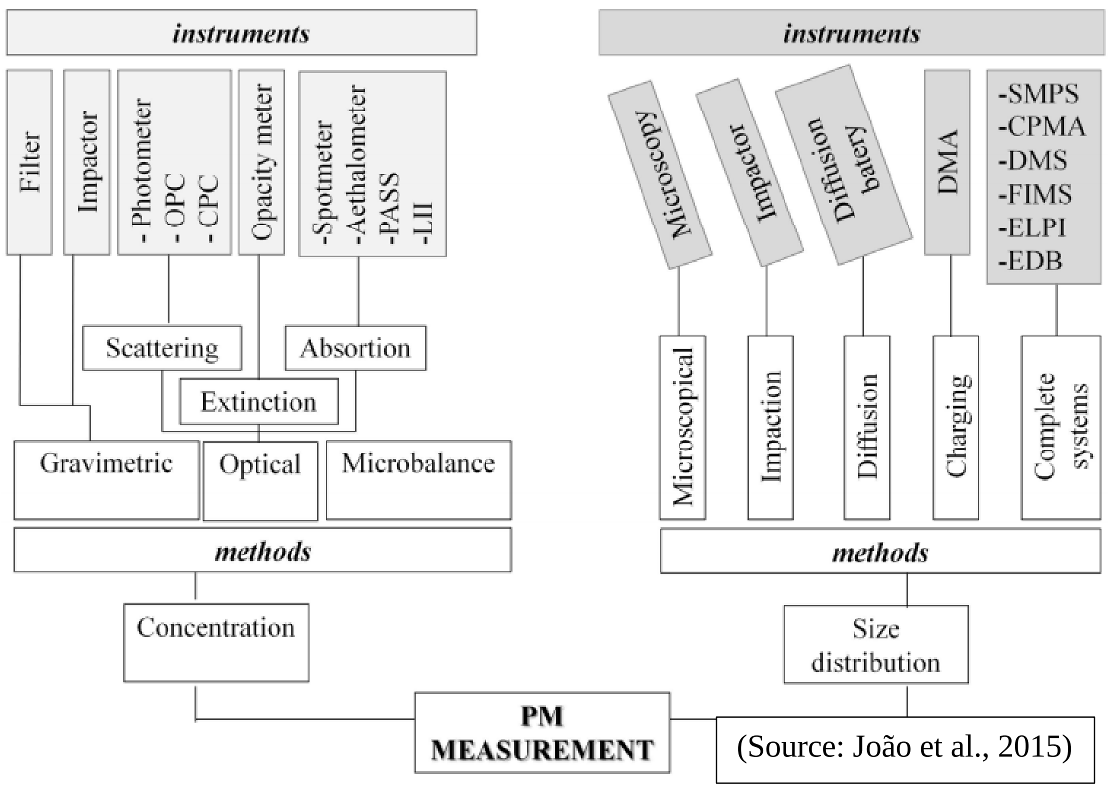


Figure 2. Methods and instruments for PM measurement.

Relevance of measuring $PM_{2.5}$ and CO

Household air pollution is a multi-faceted problem in the globe which is attributed to by different determining factors. Because of its complexity, it is difficult to manage it properly. Planning regular monitoring system of HAP for households is high relevance for further action. Currently, the HAP measurement technology are inexpensive, light weighted and can monitor for longer period. In addition, $PM_{2.5}$ and CO are known to affect human health and hence have a WHO guideline values for these pollutants. Monitoring of HAP helps to regulate the emission and manage the health outcomes. There are studies that showed the effect of household air pollution worsen the health of mothers and their children who are under-five which influences on their health especially respiratory problems (86).

Monitoring of household air pollution is used to develop and implement emission control programs to reduce air pollution. This will provide enormous economic, health, and environmental benefits. It is expected that economic effects of air quality improvement will offset the expenditures for pollution control (87).

2.7. SUMMARY OF THE LITERATURE REVIEW

Household air pollution is a global challenge, in particular to the developing nations. Ethiopia is among the least developing nation, which suffered of household air pollution. There are more than sixty types of household air pollutants registered, however, only little are given attention as a public health burden. Among the many lists of household air pollutants, cooking fuel sources are the most common and apparently addressed in the developed world. However, the use of biomass fuel still a primary source of energy for cooking in most of Ethiopian households.

The level of pollution is related to particulate matter, carbon monoxide and nitrogen dioxide were reviewed across the world. In all reviewed household pollutants, the level of pollution were higher than the global standards and limits. There are many factors, which affects the level of pollution in the house. These are, the type of kitchen ventilation, type of stove, type of cooking fuel preferences, socioeconomic and demographic determinants, housing conditions and home practices, cooking practices, environmental and behavioral factors.

Health effects related to household air pollution were reviewed in this dissertation, mainly on acute respiratory infection in underfive children. How the mechanisms of pollutants affect the health of children also reviewed. In addition, the principles, methods of pollutant measuremnts and type of devices used for pollutant measurement were described.

3. CONCEPTUAL FRAMEWORK

The outcome of interest is acute respiratory infection in under-five children. The respiratory health problem of a child is determined by the number of different factors. A child to develop a certain disease outcome (i.e. respiratory problems); it is not only a child to be exposed to household air pollution or lived in polluted environment but also other proxy factors are mandatory. These proxy factors are summarized as basic causes which include, socio-demographic factors, socio-economic factors, environmental factors and climate factors, the second is underlying causes, which include biomass fuel exposure, housing conditions (the number of openings, doors and windows), kitchen structures (the number of openings, doors and windows and availability of chimney), life style (level of awareness, meal cooking traditions), smoking habit, home cleaning, type of stove commonly used and type of fuel mostly used for cooking and the third causes are immediate causes which include pathogens that causes ARI, history of morbidity, lack of immunization and malnutrition. These confounding factors affect a child in one way or other way. All factors have no equal contribution to the problem of outcome of interest. For the sake of simplicity all contributing factors are summarized below.

Research questions

This project has three distinct research questions:

1. Does the use of biomass fuel for cooking associate with acute respiratory infection of children?
2. What are the level and its characteristics of $PM_{2.5}$ in households using biomass fuel as energy source?
3. What are the level and its characteristics of CO in households using biomass fuel as energy source?

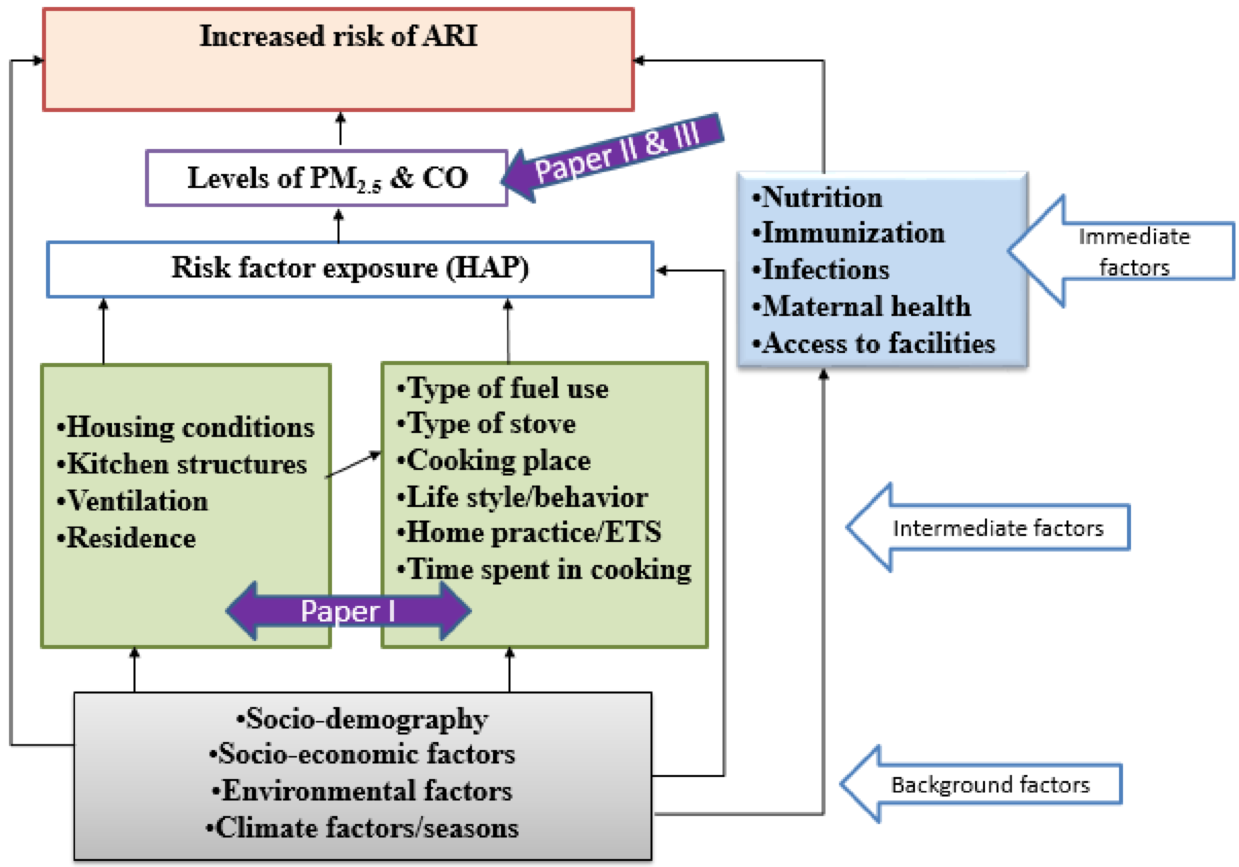


Figure 3. Conceptual framework of household air pollution and effect on ARI among children.

In this study, cooking practice of households, life style and history of smoking, home practice, characteristics of houses and kitchen, type of fuel and stove, sociodemographic and socioeconomic factors, environmental factors were addressed. However, effect of climate change, infection, morbidity and history of morbidity were not the focus of this study.

4. OBJECTIVES

GENERAL OBJECTIVES

Household air pollution and its health effect among under-five age children

SPECIFIC OBJECTIVES

I. To investigate the association between cooking fuels and acute respiratory infection in under-five children in Wolaita Sodo town, Ethiopia. **(Paper I)**

II. To determine the level, characteristics and associated factors of household Particulate Matter ($PM_{2.5}$) in cooking fuel users. **(Paper II)**

III. To determine the level, characteristics and associated factors of household Carbon monoxide (CO) in cooking fuel users. **(Paper III)**

5. RESEARCH METHODS AND MATERIALS

5.1. STUDY CONTEXT

The study was conducted from March 2016 – January 2018 in Wolaita Sodo town, which is located 329 km to Southern part of Ethiopia and 160 km from Hawassa, the Southern Nations, Nationalities and Peoples' Regional (SNNPR) State capital. Geographically it is located at 6° 49' N latitude and 39° 47' E longitude and at an altitude of about 1900 meter above sea-level.

SNNPR is one of the largest regions in Ethiopia, accounting for more than 10 percent of the country's land area and an estimated population of 20,768,000 (May 2018). With less than one in ten of its population living in urban areas (8.9%), the region is overwhelmingly rural. "The region is divided into 13 administrative zones, 133 woredas and 3512 Kebeles, and its capital is Hawassa."

"SNNPR is an extremely ethnically diverse region of Ethiopia, inhabited by more than 45 are indigenous to the region. Different languages, cultures, and socioeconomic organizations distinguish these ethnic groups. Wolaita is the second largest ethnic group in the SNNPR (11.7%) (21).

The most important source of fuel used in the households of Sodo town of Wolaita zone, were described as, firewood 94.6%, charcoal 96.6%, kerosene 11.5%, electricity 14.2%, crop residue 2.02%, dung cake 6% and saw dust 23.7%, the type of main fuel source used at the zone level was more or less similar to the town which was firewood 96.0 %, charcoal 95.2%, kerosene 15.5%, electricity 14.3%, crop residue 1.98%, dung cake 5.49% and saw dust 26.3% (88).

Wolaita Sodo town is the administrative capital city of Wolaita zone. The town has three sub cities with 11 Kebeles (the smallest administrative structure/unit of the government). According to the 2015 Wolaita zone health bureau report, the town has a population of 110,660 and has 22,584 households. The number of mothers whose age between 15-49 years old was 3829 and the number of less than five-year children was 17,277. The town has one private and one-government hospitals. There are three health centers, many private clinics and drug vendors.

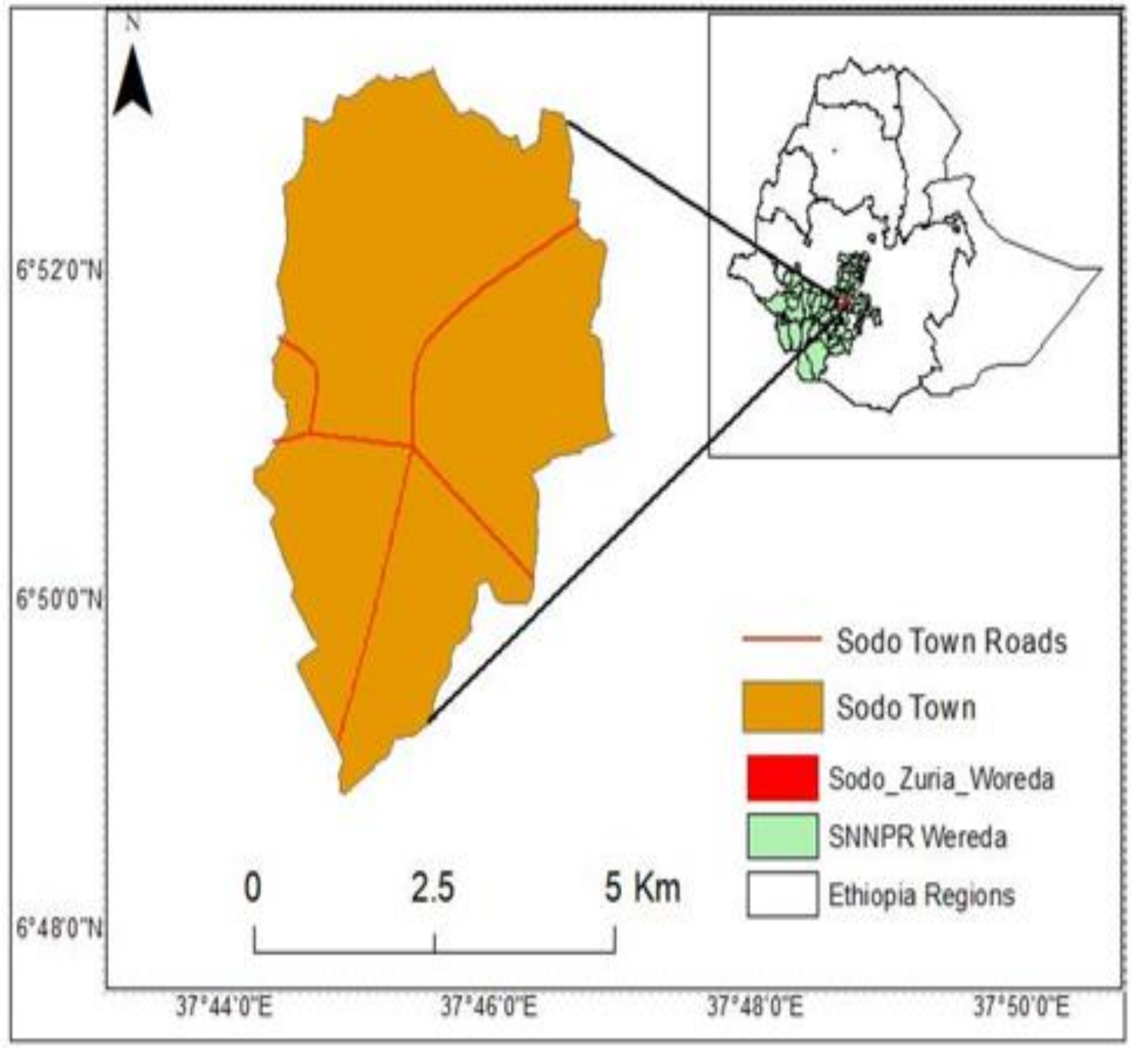


Figure 4. Location of map of study area, Wolaita Sodo town Municipality (89)

5.2. COOKING FUELS AND ACUTE RESPIRATORY INFECTIONS (PAPER I)

5.2.1. Study design

A community-based unmatched case-control study design was used to investigate the association between cooking fuel and acute respiratory infection in under-five children in Wolaita Sodo town, Ethiopia.

The choice of methods was depending on the the outcome of interest of the study. The outcome of interest of this study was health effects of household air pollution. Inorder to explore the proper causes of the disease outcome, case control study was selected. Case control study has advantages of cheaper and faster, compared with other analytic designs, useful for studying diseases with long latent periods, useful for studying rare diseases since subjects are selected on the basis of disease status and allow the investigation of multiple exposures simultaneously. However, it has a disadvantages of not suited for evaluating rare exposure unless the study is very large or the exposure is common among those with the disease, calculation of the incidence of disease in exposed and nonexposed groups cannot be performed unless the case-control study is population-based, the temporal relationship between exposure and disease cannot always be established and it is subjected to bias in identifying cases and controls (90).

Definition of cases and controls:

The prevalence of ARI in children (cases) in the census Kebeles were assessed by WHO criteria for ARI (91). Based on this definition of ARI, mothers or caregivers of children were asked if their children had been suffered from cough, followed by short, rapid breathing in the last two weeks that preceded the survey date. This definition is in agreement with existing literatures (92, 93).

5.2.2. Study populations

Source population: All under-five children whose age between 0-59 months paired with their mother or caregivers who were living in Wolaita Sodo town.

Study subjects: Children who are age between 0-59 months paired with their mother or caregiver in the absence of their mothers and who were selected in probability sampling technique.

Inclusion and exclusion criteria

All children age 0-59 months that were available to be screened for ARI during the survey time, mothers or caretakers who were available during the survey time, residents of Wolaita Sodo town (lived at least six months in Sodo town), and one child per household only (if there were two or more children in the house, participant child was selected using random system) were included in the study, while a mother or care giver of child who were seriously ill during the survey time and a child who were under treatment for confirmed tuberculosis were excluded.

5.2.3. Sample size determination

The sample size calculation was determined based on two-population proportion formula accounting for unmatched case-control study design. The design was considered a confidence level of 95%, power of 80% and ratio of number of case-to-control was 1:3, and the least extreme odds ratio to be detected was 2.00. Proportion of controls with biomass fuel exposure (17.4%) were taken from a study conducted in rural area of Nepal (9). Based on the above assumptions, the sample size was calculated by the Open Epi Version 3.03 (Open source Epidemiologic Statistics for Public Health). Having considered a design effect of 2 and a 10% of non-respondent rate, the final sample size was 1148 (i.e. 287 cases and 861 controls).

The assumption of Epi Info version 3.5.4 to calculate the sample size for unmatched case-control study design is based on the difference in proportion formula described in Kelsey et al. (94):

$$n_1 = \frac{(Z_{\alpha/2} + Z_{1-\beta})^2 \bar{p}\bar{q}(r+1)}{r(p_1 - p_2)^2}$$

and

$$n_2 = r\, n_1$$

Where,

n1= number of cases,

n2=number of controls

$Z_{\alpha/2}$ = standard normal deviate for two tailed test based on alpha level (relates to the confidence interval)

Z_{β} = standard normal deviate for one tailed test based on alpha level (relates to the power level)

r=ratio of controls to cases

P_1= the proportion of cases with exposure, q1=1-p1

P_2=the proportion of controls with exposure, q2=1-p2

$$\bar{p} = \frac{p_1 + r p_2}{r+1} \quad \text{and} \quad \bar{q} = 1 - \bar{p}$$

The sample size formula without the correction factor by Fleiss et al (95):

$\bar{p}$ =the average of P_1 and P_2, a measure of variability (similar to standard deviation)

$$n_1 = \frac{\left[Z_{\alpha/2}\sqrt{(r+1)\overline{p}\overline{q}} + Z_{1-\beta}\sqrt{rp_1q_1 + p_2q_2}\right]^2}{r(p_1 - p_2)^2}$$

$$n_2 = r\, n_1$$

For the Fleiss method with the correction factor, take the sample size from the uncorrected sample size formula and place in to the following formula:

$$n_{1cc} = \frac{n_1}{4}\left[1 + \sqrt{1 + \frac{2(r+1)}{n_1 r |p_2 - p_1|}}\right]$$

$$n_{2cc} = r\, n_{1cc}$$

When the input is provided as an odds ratio (OR) rather than the proportion of cases exposed, the proportion of cases exposed is calculated as:

$$p_1 = \frac{p_2 OR}{1 + p_2(OR - 1)}$$

5.2.4. Sampling procedure

The town has three sub cities with 11 Kebeles. Six Kebeles were selected randomly. The selected six Kebeles were assumed homogeneous characteristics. A census was conducted in the study area before the actual data collection time for setting sampling frame of study participants and to determine the prevalence of ARI among children. Then, participant subject's selection was done after the census. Cases with ARI (287 children/households) were allocated based on Probability Proportional to Size (PPS) of the population in each Kebele. Then, each household were selected using Systematic Random Sampling technique. When the case child had been once selected, then the next three consecutive control's household were interviewed. If there were two under five children in the same house, one child was selected randomly using lottery method.

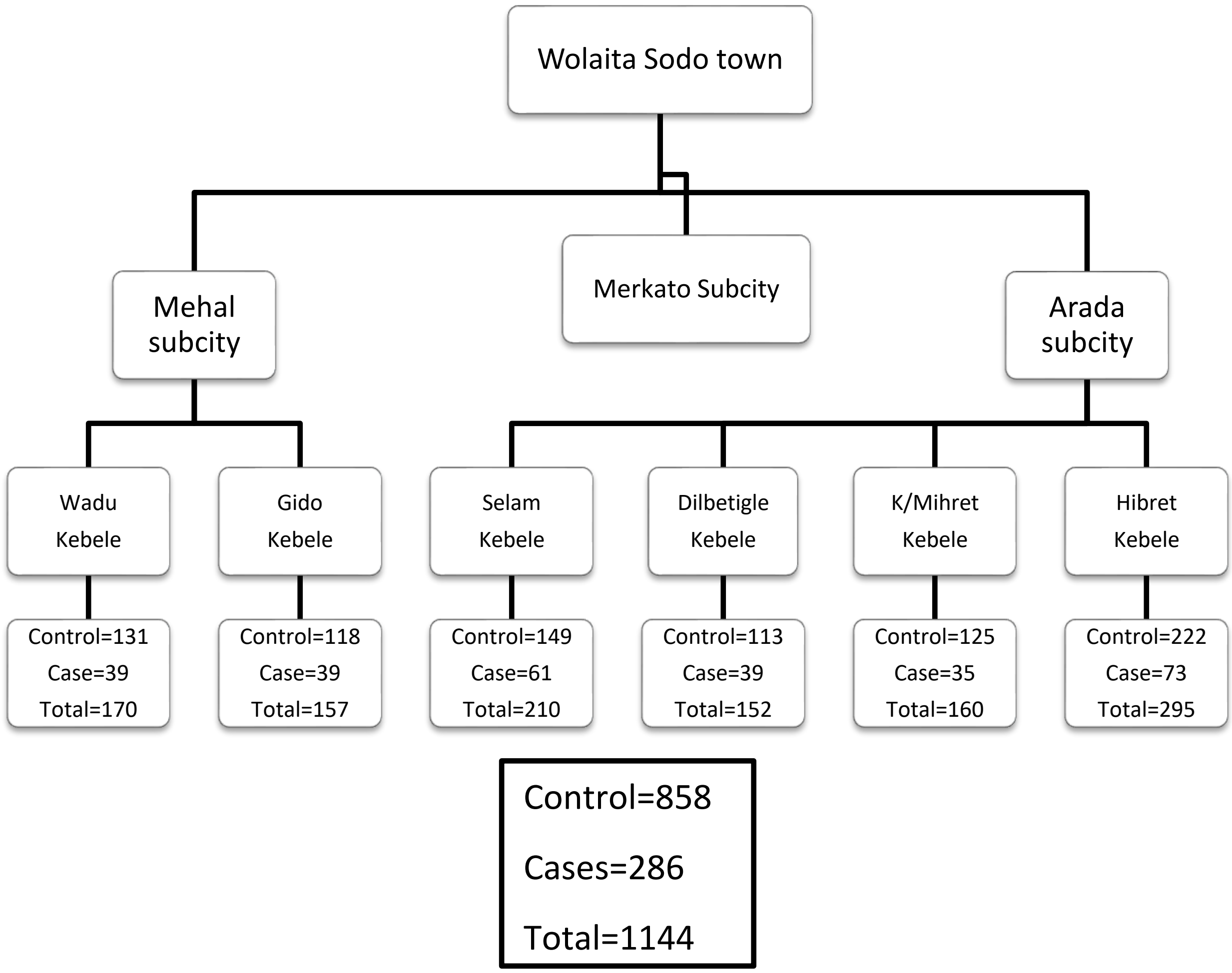


Figure 5. A diagram showing a sampling procedure for the first objective

5.2.5. Data collection procedures and tools

Two phases of data collection procedure were applied. The first phase was conducting a preliminary census and the second phase was assessing the exposure and outcome assessment tools.

Phase I: Preliminary census

The census was conducted in six Kebeles of the town before the actual data collection period (survey). The purpose of the census was to enumerate the number of households, the number of children in the houses and to identify cases with ARI and controls (determining prevalence of ARI) in under-five children. The census was conducted by trained field data collectors (10 in number) in the selected six Kebeles. The data collectors enumerated all households and all under-five age children in each household. Children's mother or guardian were requested to provide their full address and how many numbers of under-five children do they have. All households were coded to a unique number for further identification and subsequent data collection phases.

During the selection of cases and controls, mothers/guardians were asked whether their children under 5 years old had been ill with a cough during the 2 weeks preceding the survey. For children who had a cough, then the mother was additionally asked if the child, also suffered from short, rapid breathing accompanied by a fever. Children who met all of the above-mentioned criteria were regarded as having ARI. Controls were defined, if a child who had no any respiratory illness complaints, or if a child didn't suffer from cough, followed by short, rapid breathing in the last two weeks that preceded the survey date within the same population. ARI were reconfirmed by the supervisors independently using similar criteria. Based on the census result, actual data collection was designed for systematic selection of households.

Table 1. Census results of the study, Wolaita Sodo, Ethiopia, 2017

Kebele	HHs	<5children	(<5 Children)		Sample size		
			Control	Case	Control	Case	Total
Selam	1722	1317	1184	133	149	61	210
Dil Betigil	1710	1308	1176	132	113	39	152
K/Mihret	2474	1893	1701	192	128	36	164
Hibret	2420	1851	1664	187	222	73	295
Wadu	1849	1414	1271	143	131	39	170
Gido	1889	1445	1299	146	118	39	157
Sub total	**12064**	**9228**	**8294**	**934**	**861**	**287**	**1148**

Phase II: Exposure assessment using questionnaire

This assessment was conducted after the census resulted had been analyzed. Based on the census report, sufficient number of cases and control were found. Second round interview were conducted for 1148 households based on the predetermined sample size. Mother or guardians of a child were asked various questions which contains exposure variables. Interviewer administered face to face interview were followed using a close-ended structured questionnaire that contains, socio-demographic variables, the exposure related questions, fuel use, stove type, housing characteristics, type of kitchen, cooking practice, smoking history (smoking status and second-hand smoke), occupational history, and medical history etc. A questionnaire is adopted from WHO and EDHS household survey questions (21). The questionnaire was translated to local language (Amharic version) for interview. Based on these procedures, for every case there were a selection of three controls who were reside next to the case child's home. But cases and controls never been selected from the same house. When there was a large size of controls for comparison, only the first three controls were considered.

5.2.6. Data collectors

Data were collected by public health officers who took a three days training on the content of the questionnaire, how to screen cases of ARI children and control children. Each data collector conducted 5-7 pre-tests independently. Following a pre-test, the questionnaire was re-structured again and got ready. Two supervisors who took similar training were recruited. The roles of supervisors were logistic arrangement, scheduling, contact local administrators, supervising the completeness, accuracy and consistency of data, recheck or confirm cases. Completed questionnaire were collected and signed by supervisors after checked for any of concerns that could affect the quality of the data.

5.2.7. Data quality assurance:

During the census time, houses were labeled with a code number to identify one from the other and codes were recorded on the questionnaire. Regular supervision and follow-up were made by supervisors and the principal investigator. In addition, regular check-up for completeness of the questionnaire on daily basis. High emphasis was given to assure the quality of the data during designing data collection instrument. For its convenience and simplicity use of the questionnaire, pre-test was conducted on 5% (60 households) of the total sample size in non-selected Kebele (Fana Kebele). Following the pre-test, the questionnaire was revised for convenience of interviewing and data quality.

5.3. LEVELS OF HAP AMONG COOKING FUEL USERS (PAPER II & III)

5.3.1. Study designs

A Cross-sectional study design was used:

- ✓ To determine the level, characteristics and associated factors of household Particulate Matter ($PM_{2.5}$) resulted from cooking fuel users. **(Paper II)**
- ✓ To determine the level, characteristics and associated factors of household Carbon monoxide (CO) resulted from cooking fuel users. **(Paper III)**

Thw study used cross sectional study design, since the advantage of cross sectional study is to estimate the magnitude of the problem, in this case magnitude of HAP in the study area and distribution.

5.3.2. Study populations

Study population: All households in the selected Kebeles. Households, which were selected using systematic random sampling techniques from the selected Kebeles to measure the level of $PM_{2.5}$ and CO in their kitchen. Households in the selected Kebeles that used primarily biomass fuel, charcoal and electric stoves for cooking purpose were included in this study. Households were selected using systematic random sampling techniques. Mothers were available during the survey and monitoring time. Households with inconvenient kitchen for monitoring devices were excluded.

Inclusion and exclusion criteria

Houses which has at least one under-five age child, all mothers or care givers that were available in the survey time and the monitoring time, all residents of Wolaita Sodo living at least six months in Sodo were included. In case of two or more under five age children in the household, participant child was selected randomly, while the household with the type of kitchen which is open air or has no shade for it which was considered to be not convenient to use monitoring devices appropriately, and household heads who were not willing to install any monitoring equipment in their house/kitchen for any reasons were excluded.

5.3.3. Sample size determination

The measurement of $PM_{2.5}$ were conducted in selected households in the selected Kebeles. The sample size of the household's kitchens was calculated using confidence interval estimates from sample standard deviation. A recent study conducted in Gambia on household concentrations of particulate matter ($PM_{2.5}$) from biomass fuels use and exposure of children was used. Based on the Gambian study, the mean and standard deviation of $PM_{2.5}$ exposures for all subjects was 135 ±38µg/m^3 (49). Therefore, the sample size was calculated by the formula: n= $\left(\frac{Z\alpha/_2 \sigma}{d}\right)^2$ Where, n= the minimum sample size; $Z\alpha/_2$= is the desired confidence level (1.96 for 95% confidence); σ= is the population standard deviation of the outcome of interest, estimated by the sample Standard Error (SE), $SE(\sigma) = \frac{SD}{\sqrt{n}}$; d= the margin of error

The following table showed the detail sample size determination based on the assumptions.

Table 2. Assumption of the sample size calculation for the second objective, 2018

% of mean	D	(d)2	z	(z)2	SD	(SD)2	n
5.0%	6.75	45.56	1.96	3.84	38	1444.00	121.75
5.5%	7.43	55.13	1.96	3.84	38	1444.00	100.62
6.0%	8.10	65.61	1.96	3.84	38	1444.00	84.55
7.0%	9.45	89.30	1.96	3.84	38	1444.00	62.12

Based on the above assumptions and considering logistic constraints, a 5.5% (margin of error =7.43) precision of mean was considered to take a sample size of 100.62. Considering a 10% of non-response rate, the total sample size was 110 households were selected for household air pollution monitoring ($PM_{2.5}$). Both Particulate matter and carbon monoxide were planned to be monitored in all 110 households, but 66 households were monitored due to lack of access to carbon monoxide devices.

5.3.4. Sampling procedure

Among three sub cities in the town, two sub-cities were selected randomly, then six Kebeles were selected in these two sub-cities. Sample sizes were distributed to households of these six Kebeles based on Probability proportional to Size of the households in each Kebele. Each household was selected using Systematic Random Sampling technique.

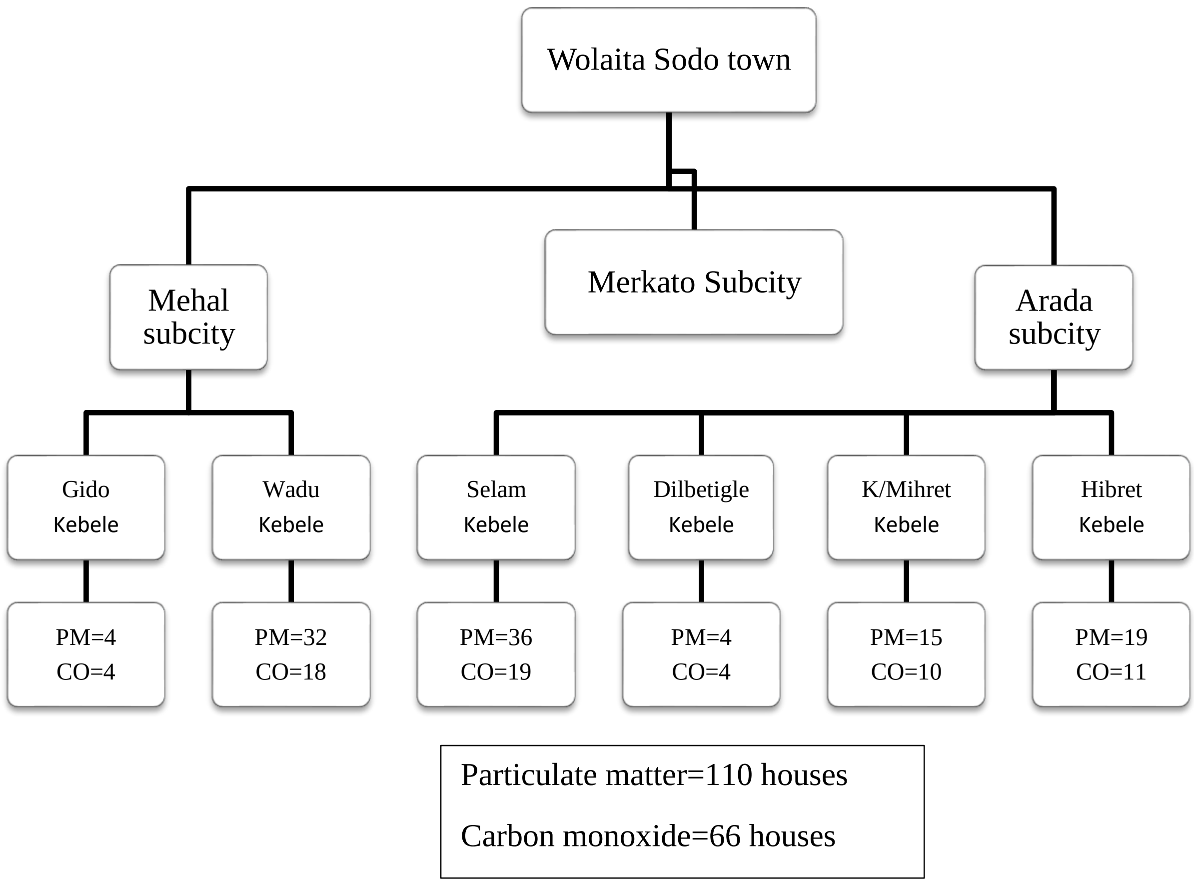


Figure 6. A diagram showing a sampling procedure for the second and third objectives

5.3.5. Data collection procedures

Particulate matter$_{2.5}$ and Carbon monoxide monitoring

Households were categorized in to biomass fuel users and mixed fuel users (biomass and electric users) based on the main sources of fuel for cooking. Each participated household were requested their verbal and written consent. Houses to be monitored for particulate matter and carbon monoxide were selected using systematic sampling. Data collectors clarified their responsibility within the framework or terms of the research protocol before starting the measurement. Data collectors informed the details and scopes of measurement protocol (i.e. duration to be monitored, safety or precaution, starting time, ending time, sounds and lighting of equipment and others). Meanwhile, an observational check list was used to observe and monitor activity pattern of the cook and other family members, the structure of house and kitchen arrangement, ventilation and other related activities in the kitchen. The monitoring duration was 24 hours. After 24 hours of measurement, devices were uninstalled and data collectors interview post measurement questions mainly the activity patterns during cooking. Finally, data collectors acknowledged the household head for their full cooperation during the interview and the monitoring time. Based on the protocol, data was downloaded from devises. The supervisor managed all doubts related to the preliminary survey, monitoring of HAP and activity pattern of the cook.

5.3.6. Data collection tools and techniques

Using monitoring devices

Both the $PM_{2.5}$ and CO were measured using optical analyzer, a portable and often battery-operated devices. Both devices have their own standard operating procedures, and these procedures were strictly followed. Monitoring conducted for 24 hours at logging rate of every minute. There were five UCB Particle Monitor (UCB-PM) loggers and three HOBO CO data loggers. One UCB-PM data logger and one HOBO CO logger and were used simultaneously in one kitchen.

Monitoring device for Particulate Matter ($PM_{2.5}$):

Particle monitors are specifically working on light scattering. Light scattering occurs when the sample introduced through the inlet nozzle is irradiated with light and then the particles pass through the light. The scattered light is detected by the photo detector and its converted to electrical signals. The size of the electrical signals represents the particle count (85). UCB-PM is a modified smoke-alarm device capable of logging changes in airborne particulate matter over extended periods and has been used successfully to measure biomass fuel smoke concentrations in developing world settings. It is optical particle monitors utilize the interaction between airborne particles and visible, infrared or laser light, commercial instruments capable of monitoring the different size fractions in a rapid cycle. The UCB-PM is a computer USB interface mood which has its own software designed to its purpose. It can be adjusted to zero noise operation when necessary. It is a small sized apparatus which is portable to transport from place to place or in the field work. It has a long battery life (96). The device has its own standard operating procedure and manual, and we followed it strictly throughout the procedures. This device was used similarly in different study areas (35, 50, 52, 55, 64, 86).

Figure 7. The UCB particles monitor (UCB-PM) used to monitor $PM_{2.5}$

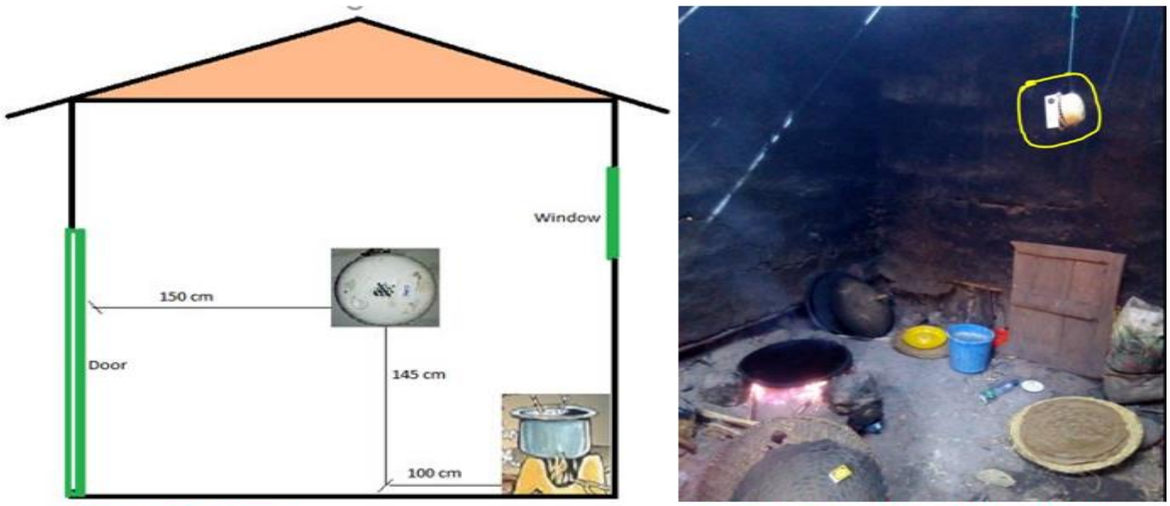
Monitoring device for Carbon monoxide:

The United States environmental protection agency-designated reference methods are automated methods utilizing the non-dispersive infrared technique, generally accepted as being the most reliable, continuous method for the measurement of CO in ambient air. Carbon monoxide has a characteristic infrared absorption near 4.6 µm. The absorption of infrared radiation by the CO molecule therefore can be used to measure CO concentration in the presence of other gases. This method was based on this principle and has several advantages. They are not sensitive to flow rate, they require no wet chemicals, they are reasonably independent of ambient air temperature changes, they are sensitive over wide concentration ranges, and they have short response times. The CO was measured using a HOBO CO Logger (model #H11-001, Onset Computer Company, Bourne, MA, USA). The devices have their own standard operating procedures, and were strictly followed these procedures. Monitoring duration were 24 hours at logging interval of every 8 seconds. These devices were used by the studies (35, 55, 64).

Figure 8. HOBO CO data Logger with USB Interface accessories

Monitoring equipment's positioning protocol:

Kitchen area monitoring of pollutants of particulate matter were measured in 110 households and carbon monoxide pollutants were measured in 66 households. A pair of devices (one UCB-PM and one HOBO CO data logger) were put simultaneously in the same household for 24 hours. Monitoring equipment's were positioned in kitchens in accordance with the standard placement protocols. According to the Center for Entrepreneurship in International Health and Development (CEIHD) School of Public Health, University of California Berkeley, a standard placement protocol of monitoring equipment stated that a device should be placed approximately 100 cm from the edge of the combustion zone (this distance away from the stove approximates the edge of the active cooking area); at a height of 145 cm above the floor (this height relates to the approximate breathing zone of a standing woman); and at least 150 cm away (horizontally) from any openable doors and windows, where possible (97).



Drawing: Amha Admasie
Photo: Amha Admasie, 18-Dec-2017: Time 10:17AM

Figure 9. Placement position of UCB PM and HOBO CO data loggers in the kitchen area

The following picture shows a traditional baking injera in a three stone stove with biomass fuel, and a monitoring device were hanging over the wall to monitor Particulate matter and carbon monoxide for 24 hour duration.

Figure 10. Installing positions of UCB PM and HOBO CO data logger in biomass fuel users

5.3.7. Data collectors

Data collectors were environmental health professionals. Two days of training was given to data collectors on the content of the questionnaire and how to measure pollutants in the kitchen area. Each data collector conducted 5-7 pre-tests. Based on the pre-test input, the questionnaire was re-structured. A supervisor was recruited and took similar training. The filled questionnaire, air sampling form and activity pattern check lists were collected and signed by supervisor after checked for any inconsistency.

5.3.8. Data quality assurance

Houses were labeled with a unique code number and the code was recorded on the questionnaire and air sampling format. Regular supervision and follow-up were made by the principal investigator. Training was given to data collectors and supervisors about $PM_{2.5}$ and CO monitoring devices on calibration of devices, mounting and down/uninstalling, operational and preventive maintenance and device handling and device transportation. All monitoring devices were calibrated at the manufacturing places before shipping to Ethiopia. The devices consistency was checked before the actual measurement. Time weighted average concentrations of each UCB PM devices were compared with each other in the same kitchen at the same time. The value of Cronbach's alpha (α) for all devices was 0.976 and the Pearson correlation coefficients of each device against the other ranges from 0.75 to 0.98. This data showed a similar result with a paired sample t-test statistic.

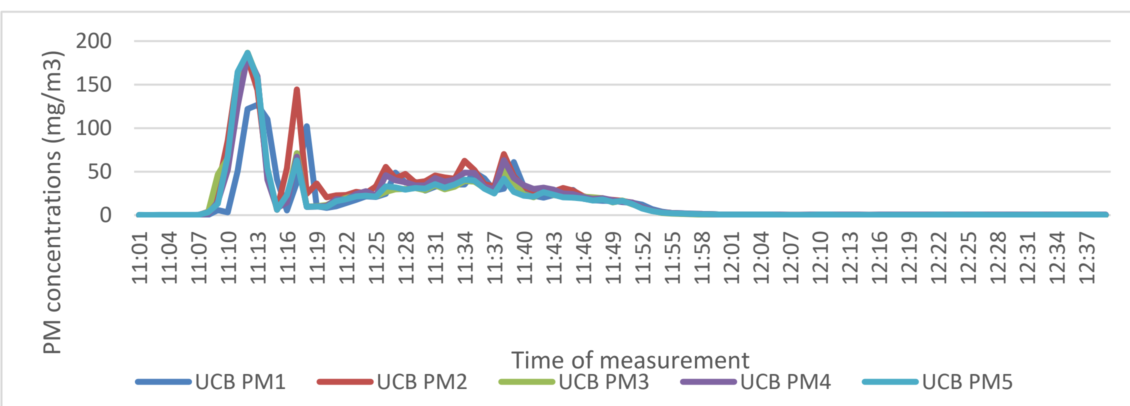


Figure 11. Graphs showing consistencies of UCB PM devices in the same kitchen at the same time

The following graph showing the HOBO CO data loggers to measure it's internal consistency of devices in a similar set up as to the actual measurement. The three devices are concurrently measures the CO with insignificance difference.

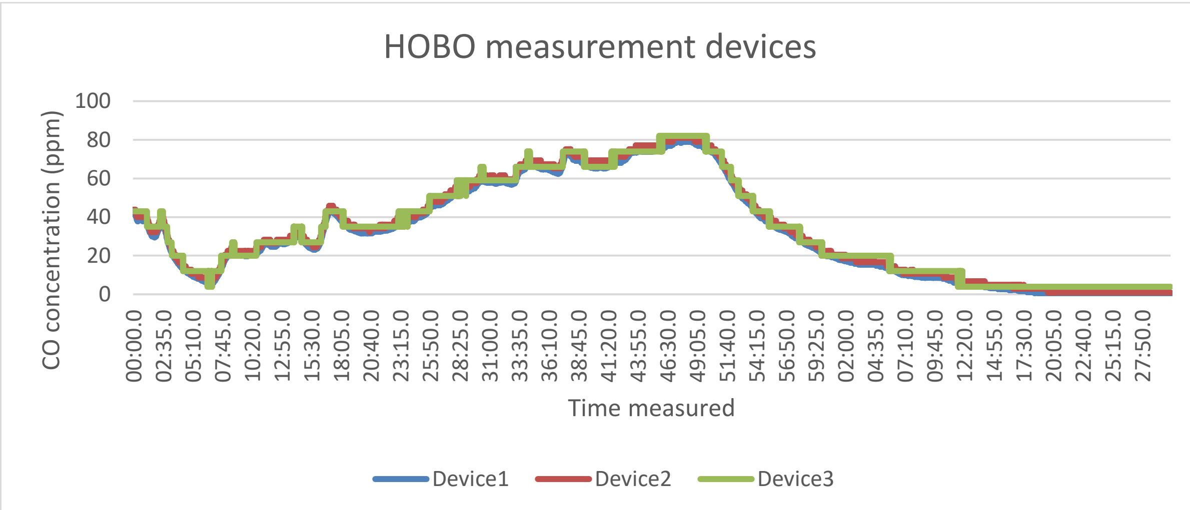


Figure 12. Graphs showing devices consistency of CO measurement

Daily configuration before and after sampling was done according the protocol. The standard operating procedures of the instruments were strictly followed in the field work activities. Air sampling data sheet and activity pattern sheet was used to record the household code and address, date and time of start, devices code, date and end time, and any remarks during the monitoring duration. Daily backup of stored data in to the computer program from all loggers was done.

Calibration: Calibration procedures consist of periodic multipoint primary calibration and secondary calibration, both of which are prescribed to minimize systematic error. Primary calibration involves at the manufacturer place, test for known concentration to an instrument in its normal mode of operation for the purpose. Therefore, all monitoring devices were calibrated at the manufacturing places before shipping to Ethiopia.

Validating the instrument: UCB PM devices were validated by the Ultrasonic Personal Aerosol Sampler (UPAS) and University of California, Berkeley-Particle and Temperature Sensor (UCB-PATS). UPAS devices are working in gravimetric analysis of particulate matters, while PATS is optical devices. It was measured in a data quality test schedule with similar setting and SOPs. The results were each other. The concentration of UCB PM were higher than that of the UPAS data. Hence, a correction factors was developed.

$$UCB\ PM\ correction\ factor = \frac{UPAS\ PM_{2.5}Concentration\ (^{\mu g}/_{m^3})}{UCB\ PM\ PM_{2.5}Concentration\ (^{\mu g}/_{m^3})}$$

Operational and preventive maintenance (secondary calibration): Consists of a zero and upscale span of the analyzer. This is recommended to be performed daily during the operation time, but since the devices are high-sensitivity measurement, cleaning of devices was applied every five measurements.

Data handling and auditing: The standard operating procedures of the instruments used and how to conduct the whole activity guideline was prepared. Data sheet to record the household code and address, date and time of start, devices code, date and end time, and any remarks during the monitoring duration was used. Daily backup of stored data in to the computer program from both loggers were applied to minimize loss data.

5.4. OPERATIONAL DEFINITIONS AND CONCEPTS

Acute respiratory infection: It is defined for a child, as those who suffered from cough, followed by rapid breathing in the two weeks that preceded the survey date.

Biomass fuel users: Households using polluting fuels users those using wood, charcoal, crop residues, leaves, straw, cow dung, tree branches for most of the cooking events all the time.

Carbon monoxide: is a colorless, non-irritant, odorless and tasteless toxic gas. It is produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, coal, natural gas and kerosene.

Case: A child who has fulfilled the criteria of acute respiratory infection (i.e. a child who suffered from cough, followed by rapid breathing in the two weeks that preceded the survey date).

Clean fuel users: Households, which are using clean fuels (i.e. electricity, LPG, natural gas and biogas) for cooking purposes.

Control: A child who is free of any complaints of respiratory illnesses in the two weeks that preceded the survey date.

Coarse particles: are the relatively large airborne particles mainly produced by the mechanical break-up of even larger solid particles, having an aerodynamic diameter ranging from 2.5 to 10µm ($PM_{10-2.5}$), which distinguishes them from the smaller airborne particulate matter referred to as **fine particulate matter** ($PM_{2.5}$) and **ultrafine particles** ($PM_{0.1}$).

House ventilation: Poor ventilation (a house with only one room, one door and no or only one window), moderate ventilation (a house with two rooms two doors and two windows), and good ventilation (a house with three or more rooms, doors, and windows).

Mixed fuel users: Households, which are using both biomass and clean fuels.

Particulate matter: Sum of all microscopic solid and liquid particles, of human and natural origin, that remain suspended in a medium such as air for some time. These particles vary greatly in size, composition, and origin, and may be harmful.

5.5. DATA MANAGEMENT AND ANALYSIS

The completed questionnaire was collected and identification number was given to each questionnaire. All eligible questionnaire was entered in to computer software program for analysis, in Epi Data version 3.1 and exported to SPSS version 21. Then data were cleaned for missing values, inconsistencies, outliers and other irregularities by running frequencies.

Further statistical analysis, descriptive statistics (frequency, proportions, mean, median, standard deviation, interquartile range, tables, and graphs), comparisons of proportions among categorical variables were made using chi-squared test, similarly, associations between numeric variables were tested using simple correlation analysis.

Unconditional logistic regression and multivariable logistic regressions were run using hierarchical model. One of the dependent variables was ARI, cases with ARI were coded as 1 and controls were coded as 0. Crude odds ratio (COR) and Adjusted odds ratio (AOR) with 95% confidence interval were evaluated based on the criteria. Significantly associated variables at p-values <0.05 cut off point in unconditional bivariate logistic regression analysis were entered in to a multivariable analysis using Enter method of regression. Predictor variables were tested for multi co-linearity tests using Variance Inflation Factor (VIF) <10 and Tolerance Test > 0.1 prior to multivariate analysis. Hosmer-Lemeshow goodness-of-fit test was used in multivariate analysis to check the adequacy of the model. In all tests statistical significance was judged at p-values was <0.05.

The $PM_{2.5}$ data were downloaded to UCB Monitor Manager software (Version 2.1.3) and CO data were downloaded to BoxCar Pro software (Version 4.3). Kolmogorov-Smirnov and Shapiro-Wilk Arithmetic test of normality was checked and later the data was transformed to logarithm. Mean, standard deviation, median, percentiles, minimum and maximum values and Analysis of Variance (ANOVA) for different fuel sources were analysed. The correlation test between categorical variables and level of concentrations of particulate matter were analyzed using the “Eta statistics”. The level of $PM_{2.5}$ and CO data were compared with the World Health Organization Air Quality Guideline (AQG) values. Finally, data were presented in Tables, narrations and Figures.

5.6. ETHICAL CONSIDERATION:

Permission to undertake this study was obtained from School of Public Health, Addis Ababa University, Research Ethical Committee and Institutional Review Board of the College of Health Sciences. Official letter of co-operation was given to Wolaita Sodo Town Administrative and Health offices. Informed consent to participate in the study was from each participant obtained before conducting the interview. For this, a one-page consent letter was attached to the cover page of each questionnaire and it explained to the study participants that participation is voluntary and confidential and private information was protected, that means any of the information gained from them was not be provided for the third party. The information they provided were not used for other purpose other than to the objectives clearly stated on the consent paper. The right of the respondent to withdraw from the interview or not to participate was respected. The potential benefits of involving in this research was clearly explained and clarified. The research had no any risk to the participant as well as to the whole family too.

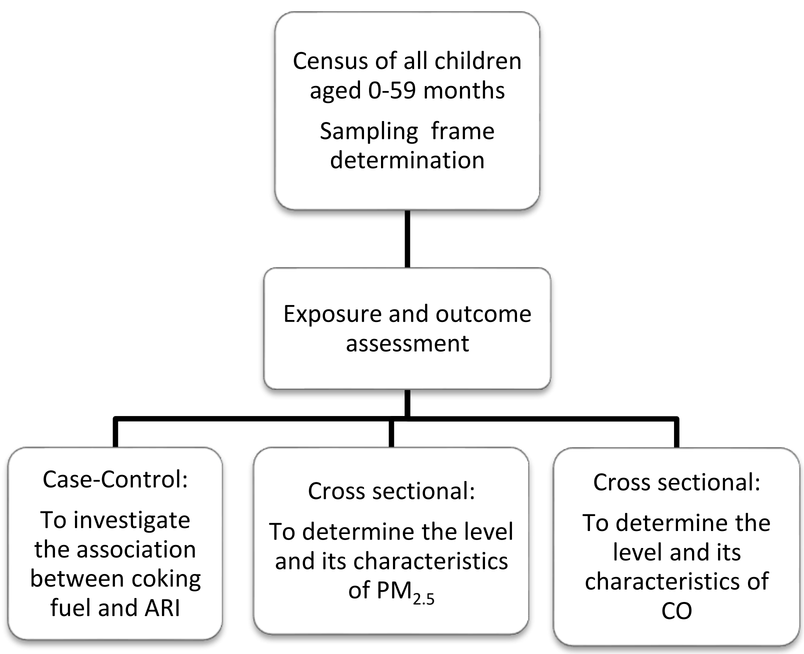


Figure 13. Summary of study design, methods and procedures

5.7. SUMMARY OF THE DISSERTATION WORK

Table 3. Summary table of the dissertation work

Methods	Paper I	Paper II	Paper III
Objective	To investigate the association between biomass fuel and ARI among under-five children	To determine the level, characteristics and associated factors of household $PM_{2.5}$ in biomass fuel users	To determine the level, characteristics and associated factors of household CO in biomass fuel users
Design	Case control	Cross-sectional	Cross-sectional
Study population	Children aged, 0-59 months	Kitchen/Houses	Kitchen/Houses
Sample size	1148 children	110	66
Sampling	Simple random & SRS	Simple random & SRS	Simple random & SRS
Outcome variable	ARI	Level and characterization	Level and characterization
Tools	Questionnaire	Questionnaire, Observation Check list, UCB-PM device	Questionnaire, Observational check-list, HOBO CO Data Logger
Data quality and management	Check completeness, Data entry, Cleaning & coding	Calibration, validation, Data handling and auditing	Calibration, validation, Data handling and auditing
Statistical analysis	Unconditional Logistic Regression, Bivariate and Multivariable LR, Odds Ratio	Linear regression, Discriptives, ANOVA, Percentiles, Correlation (Eta-test)	Linear regression, Discriptives, ANOVA, Percentiles, Correlation (Eta-test)

6. RESULTS

6.1. COOKING FUELS AND ARI CHILDREN (PAPER I)

6.1.1. Prevalence of acute respiratory tract infection

The census was conducted in six Kebeles of the town before the actual data collection period (survey). In all six Kebeles 9228, children were found. Out of these, 934 children had been identified with ARI (children suffered from cough, followed by short, rapid breathing in the last two weeks that preceded the survey date). Hence, the prevalence of ARI in under five children was 10.1% (95% CI 9.5, 10.8).

6.1.2. Socio-demographic characteristics

A total of 1144 children (286 cases and 858 controls) were included in the study with response rate of 99.65%. The mean age of the mother was 26.89±6.0 years. Two hundred ten (18.36%) of mothers were employed, while 544 (47.55%) were housewives. Eight hundred thirty-one (72.6%) of the households had a family of five or less. Education of mothers, employment status of mothers and family size were statistically significant with acute respiratory infections of children, while age of mother, main drinking water and type of household latrine were not showing a significance differences acute respiratory infection of children (Table 4).

Table 4. Socio-demography and ARI in children, Wolaita-Sodo, Feb 2017

Variables (n=1144)		Case, n (%)	Control, n (%)	Total, n (%)	χ^2(P-value)
Mother age	15-24 years	94 (32.9)	252 (29.4)	346 (30.24)	1.62 (0.44)
	25-44 years	189 (66.1)	592 (69.0)	781 (68.26)	
	45+ years	3 (1.5)	14 (1.6)	17 (1.48)	
Mother educational status	No education	98 (34.3)	233 (27.2)	331 (28.9)	37.76 **(<0.001)**
	Primary level	109 (38.1)	217 (25.3)	326 (28.5)	
	Secondary level	46 (16.1)	200 (23.3)	246 (21.5)	
	Higher level	33 (11.5)	208 (24.2)	241 (21.1)	
Mother employment	Employed	30 (10.5)	180 (21.0)	210 (18.36)	
	Petty trade	37 (12.9)	168 (19.6)	205 (17.92)	29.15
	Unemployed	61 (21.3)	124 (14.5)	185 (16.2)	**(<0.001)**
	Housewife	158 (55.2)	386 (45.0)	544 (47.55)	
Family size	≤5 Families	190 (66.4)	641 (74.7)	831 (72.6)	7.391
	>5 Families	96 (33.6)	217 (25.3)	313 (27.4)	**(<0.001)**
Main drinking water source	Improved	264 (92.3)	817 (95.2)	1081 (94.5)	3.5
	Non-Improved	22 (7.7)	41 (4.8)	63 (5.5)	(0.061)
The type of latrine	No latrine	10 (3.5)	40 (4.7)	50 (4.4)	
	Pit latrine	246 (86.0)	726 (84.6)	972 (85.0)	2.14
	VIPL	21 (7.3)	74 (8.6)	95 (8.3)	(0.544)
	Water Pour	9 (3.1)	18 (2.1)	27 (2.4)	

*Bolded values are significant at p-value <0.05

6.1.3. Maternal and child related variables

Children were relatively equally distributed by age. The mean age of the children was 24.15±14.98 month. Age group between 12-23 months were the largest, 330 (28.86%). Males accounted 606 (52.97%) of the total children. Almost half of the children, 642 (56.1%) of children had a birth interval of less or equal to two years. Seven hundred forty-five (65.12%) of children shared their bed room with two peoples. Child age and sex; Antenatal Care (ANC) follow-up of mothers, bedroom shared with other family members and time of breast feeding started were not showing significant differences with acute respiratory infections of the child, while only birth interval of a child had significance differences with acute respiratory infections of the child (Table 5).

Table 5. Maternal and child variables and ARI in children, W/Sodo, Ethiopia, Feb, 2017

Characteristics (n=1144)		**Case, n (%)**	**Control, n (%)**	**Total, n (%)**	**χ^2 (P-value)**
Sex of the child	Male	145 (50.7)	461 (53.7)	606 (53.0)	0.791 (0.374)
	Female	141 (49.3)	397 (46.3)	538 (47.0)	
Child age	0-11 months	62 (21.7)	219 (25.5)	281 (24.6)	6.942 (0.139)
	12-23 months	99 (34.6)	231 (26.9)	330 (28.8)	
	24-35 months	57 (19.9)	202 (23.5)	259 (22.6)	
	36-47 months	43 (15.0)	129 (15.0)	172 (15.0)	
	48-59 months	25 (8.7)	77 (9.0)	102 (8.9)	
ANC follow up	Yes	274 (95.8)	832 (97.0)	1106 (96.7)	0.904 (0.341)
	No	12 (4.2)	26 (3.0)	38 (3.3)	
Birth interval	≤2 years	177 (61.9)	465 (54.2)	642 (56.1)	5.15 (**0.023**)
	>2 years	109 (38.1)	393 (45.8)	502 (43.9)	
Bedroom shared with the child	1 person	48 (16.8)	157 (18.3)	205 (17.9)	0.612 (0.736)
	2 persons	186 (65.0)	559 (65.2)	745 (65.1)	
	>=3 Persons	52 (18.2)	142 (16.6)	194 (17.0)	

*Bolded values are significant at p-value <0.05

6.1.4. Kitchen and housing characteristics

About 712 (62.23%) of households had a kitchen separated from the main house, while 351 (30.68%) of households had kitchen inside the living house. Only, 417 (58.5%) of the kitchen had no chimney, 666 (93.54%) didn't open windows during the cooking time. About 508 (44.4%) of children were lived in the house of one window. Kitchen arrangement, number of rooms and windows; kitchen chimney had significantly correlated with acute respiratory infection of children, while floor materials of the kitchen, windows opening while cooking had no a significance relation with acute respiratory infection of the child (Table 6).

Table 6. Kitchen and house characteristics and ARI in children, W/Sodo, Ethiopia, Feb, 2017

Kitchen and house variables (n=1144)		Case (%)	Control (%)	Total (%)	χ^2 (P-value)
Kitchen arrangement	Inside the house	125 (43.7)	226 (26.3)	351 (30.7)	35.78
	Separate building	136 (47.6)	576 (67.1)	712 (62.2)	**(<0.001)**
	Outdoor/open	25 (8.7)	56 (6.5)	81 (7.1)	
Kitchen have a chimney	Yes	9 (3.1)	32 (3.1)	41 (3.6)	2.61
	No	277 (96.9)	826 (96.3)	1103 (96.4)	(0.106)
Floor material of house	Soil/mud	167(58.4)	457 (53.3)	624 (54.5)	2.27
	Cement	119 (41.6)	401 (46.7)	520 (45.5)	(0.131)
# of rooms	1 room	118 (41.3)	229 (26.7)	347 (30.3)	22.71
	2 rooms	106 (37.1)	366 (42.7)	472 (41.3)	**(<0.001)**
	≥3 rooms	62 (21.7)	263 (30.7)	325 (28.4)	
# of windows	No window	22 (7.7)	42 (4.9)	64 (5.6)	28.27
	1 window	159 (55.6)	349 (40.7)	508 (44.4)	**(<0.001)**
	2 windows	67 (23.4)	325 (37.9)	392 (34.3)	
	≥3 windows	38 (13.3)	142 (16.6)	180 (15.7)	
Windows open during the visit	Yes	125 (43.7)	451 (52.6)	576 (50.3)	6.73
	No	161 (56.3)	407 (47.4)	568 (49.7)	**(0.009)**

*Bolded values are significant at p-value <0.05

The following pictures showed the three stone stove and improved stove. Both are traditional type of stoves, but the improved stove have chimney for smoke and heat exhaust to the outside of the kitchen.

Figure 14. Traditional three stone stove and improved stove, W/Sodo, Ethiopia, 2018

6.1.5. Type of fuel, stove and home practice

Almost more than three-fourth of children live in households that used biomass fuels, 1001 (87.5%) and only 143 (12.5%) of the households were used mixed type of fuel (electricity, biogas and Liquefied Petroleum Gas (LPG) and biomass. The majority 950 (83.04%) of the households used open/traditional three stone stoves. Five hundred fifty-two, (44.75%) of the respondents spent at least 2 hours per day in cooking foods. Only one-third of the children were present around the cooking stove while mothers were cooking meal. Almost less than one-third of children had a habit of being carried by their mothers or care giver while cooking meal. Type of fuel mainly used for cooking, type of cooking stove usually used, children usually present around cooking area, a mother's habit of carrying their children and smoking history of family members were significantly associated with the acute respiratory infection of children, but time spent in cooking had no significant correlations (Table 7).

Table 7. Fuel and stove types and ARI in children, W/Sodo, Ethiopia, Feb, 2017

Fuel and stove types (n=1144)		Case (%)	Control (%)	Total (%)	χ^2 (p-value)
Type of fuel for cooking	Mixed	21 (7.3)	122 (14.2)	143 (12.5)	9.27
	Biomass	265 (92.7)	736 (85.8)	1001 (87.5)	**(0.002)**
Type of cooking stove	Open stove	258 (90.2)	692 (80.7)	950 (83.0)	15.32
	Improved	28 (9.8)	166 (19.3)	194 (17.0)	**(<0.001)**
Time spent in cooking	1 hour	66 (23.1)	205 (23.9)	271 (23.7)	2.13
	2 hours	120 (42.0)	392 (45.7)	512 (44.8)	(0.344)
	3+ hours	100 (35.0)	261 (30.4)	361 (31.6)	
Child usually present during cooking	Yes	123 (43.0)	260 (30.3)	383 (33.5)	15.54
	No	163 (57.0)	598 (69.7)	761 (66.5)	**(<0.001)**
Carrying a child while cooking	Yes	106 (37.1)	202 (23.5)	308 (26.9)	19.92
	No	180 (62.9)	656 (76.5)	836 (73.1)	(<0.001)
Family smokes cigarette	Yes	11 (3.8)	11 (1.3)	22 (1.9)	7.47
	No	275 (96.2)	847 (98.7)	1122 (98.1)	**(0.006)**

***** Bolded values are significant at p-value <0.05

The following pictures indicating how biomass fuel for cooking and heating emits high level of smokes even to the ambient environment. Such type of smokes most likely from tree leaves, cow dungs and agricultural residues, straw, bushes. The content of moisture in the source of fuel could be the source of high smoke.

In the right side picture shows a mother bake injera in a traditional cooking stove. The stove is a partially improved, but the smoke and fire heat is not minimized.

Figure 15. Combustion of biomass fuel in a poorly ventilated house, W/Sodo, Ethiopia, 2018

Table 8. Bivariate logistic regression results of predictor variables of ARI, W/Sodo, Ethiopia

A. Sociodemographic variables

Predicting variables	Categories	ARI		P-value	COR (95% CI)
		Control	Case		
Mother age	15-24 years	252	94	0.392	1.74 (0.48-6.19)
	25-44 years	592	189	0.534	1.49 (0.42-5.24)
	45+ years	14	3		1.00
Marital status	Married	823	266	0.04	0.56 (0.31-0.99)
	Other	35	20		1.00
Education of mother	Illiterate	233	98	0.022	1.39 (1.05-1.86)
	Literate	625	188		1.00
Educational of father	No education	161	64	0.362	1.19 (0.81-1.76)
	Primary level	219	76	0.812	1.04 (0.72-1.50)
	Secondary level	246	69	0.374	0.84 (0.58-1.22)
	Higher level	232	77		1.00
Mother employment	Employed	180	30	0.000	0.40 (0.26-0.62)
	Petty trade	168	37	0.002	0.53 (0.36-0.80)
	Unemployed	124	61	0.314	1.20 (0.84-1.71)
	Housewife	386	158		1.00
Father employment	Employed	440	133	0.532	0.78 (0.37-1.67)
	Petty trade	201	63	0.608	0.81 (0.37-1.78)
	Daily laborer	154	66	0.787	(1.11 (0.50-2.44)
	Unemployed	37	14	0.973	0.98 (0.37-2.55)
	Others	26	10		1.00
Family size	≤5 Families	641	190	0.007	0.67 (0.50-0.89)
	>5 Families	217	96		1.00
Monthly income of the household	<1000 Birr	244	121	0.000	3.28 (1.91-5.63)
	1000-3000 Birr	362	110	0.011	2.01 (1.17-3.45)
	3001-5000 Birr	133	37	0.052	1.84 (0.99-3.40)
	>5000 Birr	119	18		1.00
House ownership	Own house	317	90	0.094	0.78 (0.59-1.04)
	Rent house	541	196		1.00
Water source	Protected source	817	264	0.064	0.60 (0.35-1.03)
	Unprotected	41	22		1.00
Time to obtain drinking water in round trip	Inside premises	528	130	0.000	0.25 (0.15-0.42)
	<30 Minutes	293	120	0.001	0.42 (0.25-0.70)
	>30 Minutes	37	36		1.00
The type of latrine	No latrine	40	10	0.199	0.50 (0.17-1.44)
	Pit latrine	726	246	0.348	0.68 (0.30-1.53)
	VIPL	74	21	0.235	0.57 (0.22-1.45)
	Water Pour	18	9		1.00

B. Child health related variables

Predicting variables	Categories	ARI		P-value	COR (95% CI)
		Control	Case		
Number of children	One child	726	243	0.429	1.84 (0.40-8.36)
	Two children	121	41	0.430	1.86 (0.39-8.76)
	≥Three children	11	2		1.00
Sex of a child	Male	461	145	0.374	0.89 (0.68-1.16)
	Female	397	141		1.00
Child age	0-11 months	219	62	0.872	0.87 (0.51-1.48)
	12-23 months	231	99	1.320	1.32 (0.79-2.20)
	24-35 months	202	57	0.610	0.87 (0.51-1.49)
	36-47 months	129	43	0.928	1.03 (0.58-1.81)
	48-59 months	77	25		1.00
Birth weight	Small	138	48	0.328	1.28 (0.78-2.11)
	Average	591	203	0.255	1.27 (0.84-1.90)
	Large	129	35		1.00
Birth interval/order	≤2 years	465	177	0.023	1.37 (1.04-1.80)
	>2 years	393	109		1.00
The child born at full term	Yes	837	279	1.00	1.00 (0.42-2.38)
	No/Don't Know	21	7		1.00
ANC follow up	Yes	832	274	0.343	0.71 (0.36-1.43)
	No	26	12		1.00
Place of child born	Home delivery	82	23	0.749	1.12 (0.55-2.27)
	Gov't facilities	708	246	0.242	1.39 (0.80-2.41)
	Private facilities	68	17		1.00
The child attends school	Yes	143	60	0.099	1.33 (0.95-1.86)
	No	715	226		1.00
Number of people share child's bedroom	1 person	157	48	0.435	0.83 (0.53-1.31)
	2 persons	559	186	0.600	0.91 (0.63-1.30)
	≥3 Persons	142	52		1.00
Child breast feeding status	Yes	739	246	0.536	1.41 (0.47-4.24)
	No	102	36	0.491	1.50 (0.47-4.75)
	Don't know	17	4		1.00
Breast feeding starting time	< One hour	650	214	0.301	0.61 (0.24-1.55)
	< In 24 hour	76	25	0.346	0.61 (0.22-1.70)
	>24 hour	13	7		1.00
Supplementary foods start time	Not yet started	80	25	0.798	0.94 (0.59-1.51)
	<6 months	53	20	0.642	1.14 (0.67-1.94)
	≥6 months	725	241		1.00
Immunization status	Yes	726	236	0.401	0.86 (0.60-1.23)
	Partially/No	132	50		1.00
Child handwashing with soap at critical times	Yes	596	193	0.531	0.91 (0.68-1.22)
	No	262	93		1.00

C. House characteristics

Predicting variables	Categories	ARI		P-value	COR (95% CI)
		Control	Case		
Year of house constructed	The last 10 years	242	60	0.009	0.62 (0.44-0.89)
	Before 10 years	286	96	0.309	0.85 (0.62-1.15)
	Don't know	330	130		1.00
Number of rooms	1 room	229	118	0.000	2.18(1.53-3.11)
	2 rooms	366	106	0.251	1.22(0.86-1.74)
	3+ rooms	263	62		1.00
Number of windows	No window	42	22	0.036	1.95(1.04-3.66)
	1 window	349	159	0.100	1.70(1.13-2.55)
	2 windows	325	67	0.250	0.77(0.49-1.20)
	3+ windows	142	38		1.00
Number of doors	1 door	377	176	0.002	1.90 (1.27-2.84)
	2 doors	330	73	0.649	0.90 (0.58-1.40)
	3+ doors	151	37		1.00
Any openings in the house	Yes	57	22	0.545	1.17 (0.70-1.95)
	No	801	264		1.00
Floor material of the house	Soil/mud	457	167	0.132	1.23 (0.93-1.61)
	Cement	401	119		1.00
Wall material of the house	Wood/Bamboo	173	49	0.689	0.88 (0.47-1.63)
	Mud	629	219	0.777	1.08 (0.62-1.88)
	Blocks/stone	56	18		1.00
House ventilation level	Poor	288	186	0.000	4.62 (2.92-7.30)
	Moderate	391	75	0.201	1.37 (0.84-2.23)
	Good	179	25		1.00

D. Kitchen characteristics

Predicting variables	Categories	ARI		P-value	COR (95% CI)
		Control	Case		
Kitchen arrangement	Inside the house	226	125	0.419	1.23 (0.73-2.08)
	Separate building	576	136	0.014	0.52 (0.31-0.87)
	Outdoor	56	25		1.00
Any openings in the kitchen	Yes	381	86	0.521	0.88 (0.60-1.30)
	No	195	50		1.00
Kitchen have a chimney	Yes	247	48	0.107	0.73 (0.49-1.07)
	No	329	88		
Floor material of the kitchen	Soil/mud	533	127	0.733	1.13 (0.54-2.39)
	Cement/Ceramic	43	9		1.00
Open windows during the time of cooking	Yes	275	52	0.046	0.68 (0.46-0.99)
	No	301	84		1.00
The stove is under any shed, roof or canopy	Yes	13	1	0.064	0.13 (0.01-1.11)
	No	43	24		1.00

E. Fuel and stove types

Predicting variables	Categories	ARI		P-value	COR (95% CI)
		Control	Case		
Type of fuel for cooking	Mixed fuel	122	21	0.003	0.47 (0.29-0.77)
	Biomass fuel	736	265		1.00
Usual stove use for cooking	Open stove	692	258	0.000	2.21 (1.44-3.38)
	Improved stove	166	28		
Frequency of stove ignition in a day	Once	143	42	0.410	0.84 (0.56-1.27)
	Twice	414	139	0.799	0.96 (0.72-1.29)
	>=3 times	301	105		1.00
Time spent in cooking	1 hour	205	66	0.344	0.84 (0.58-1.20)
	2 hours	392	120	0.153	0.79 (0.58-1.08)
	3+ hours	261	100		1.00
Baking injera in the house	Yes	627	200	0.303	0.86 (0.64-1.15)
	No	231	86		1.00
Frequency of baking injera in a week	Once	103	36	0.700	0.91 (0.55-1.50)
	Twice	397	115	0.149	0.75 (0.51-1.11)
	>=3 times	127	49		1.00
Baking injera/food for commercial purpose	Yes	76	29	0.516	1.16 (0.74-1.82)
	No	782	257		1.00
Frequency of kitchen cleaning	Once	116	53	0.077	1.42 (0.96-2.10)
	Twice	255	77	0.710	0.94 (0.67-1.31)
	>Twice	145	46	0.946	0.99 (0.66-1.46)
	Daily	342	110		1.00
Child usually present during cooking	Yes	260	123	0.000	1.73 (1.31-2.28)
	No	598	163		1.00
Habit of carrying a child while cooking	Yes	202	106	0.000	1.91 (1.43-2.54)
	No	656	180		1.00
Smoke incense frequently	Yes	586	195	0.971	0.99 (0.75-1.33)
	No	272	91		1.00
Family member smoke cigarette	Yes	11	11	0.009	3.08 (1.32-7.18)
	No	847	275		1.00

F. Observation during the visit

Predicting variables	Categories	ARI		P-value	COR (95% CI)
		Control	Case		
The house has window	Yes	798	257	0.666	0.67 (0.42-1.06)
	No	60	29		1.00
Window opened during the visit	Yes	451	125	0.010	0.70 (0.54-0.92)
	No	407	161		1.00
Any openings in house for natural ventilation	Yes	491	137	0.006	0.69 (0.53-0.90)
	No	367	149		1.00
Are openings sufficient for house ventilation	Yes	423	106	0.000	0.60 (0.46-0.79)
	No	435	180		
Functional chimney in the house	Yes	32	9	0.64	0.84 (0.40-1.78)
	No	826	277		1.00
The house looks black due to smoke	Yes	115	60	0.002	1.72 (1.21-2.42)
	No	743	226		1.00
The kitchen has window	Yes	369	96	0.009	0.68 (0.51-0.91)
	No	433	165		1.00
Any openings in kitchen for natural ventilation	Yes	508	145		0.72 (0.54-0.96)
	No	294	116		1.00
Kitchen's openings sufficient for ventilation	Yes	393	99	0.002	0.63 (0.47-0.84)
	No	409	162		1.00
Functional chimney in the kitchen	Yes	59	13	0.187	0.66 (0.35-1.22)
	No	743	248		1.00
The kitchen looks black due to smoke	Yes	575	198	0.190	1.24 (0.89-1.71)
	No	227	63		1..00
Sufficient distance b/n kitchen and house	Yes	513	149	0.047	0.75 (0.56-1.00)
	No	289	112		1.00
The kitchen serve for other purposes	Yes	104	33	0.892	0.97 (0.63-1.47)
	No	698	228		1.00
The kitchen is clean enough	Yes	456	123	0.006	0.68 (0.51-0.90)
	No	346	138		1.00

Multivariable logistic regression analysis

Predictor variables of acute respiratory infection in under five children were analyzed using binary logistic regression, and hence significantly associated variables at $p<0.05$ in bivariate analysis were entered to the multivariable logistic regression in hierarchal model. In the first model, type of fuel for cooking, cooking place, type of stove usually used and ventilation of houses were entered. In the second model number of windows and rooms, child usually present during cooking, habit of carrying child and family cigarette smoking were entered; and in the last model, education of mothers, employment status, family size and child birth interval were entered. Biomass fuel used for cooking (AOR: 2.08, 95% CI 1.03-4.22), poorly ventilated houses (AOR: 4.31, 95% CI 2.60-7.15), family size of more than 5 (AOR: 1.85, 95% CI 1.30-2.61) and child birth spacing less than 2 years (AOR: 1.40, 95% CI 1.02-1.91) showed a significant effect on children ARI in reference to mixed fuels (Electricity, LPG, Biogas and biomass), good ventilation house, family size of less than 5 and child birth spacing greater than five years (Table 9).

Table 9. Logistic regression model for ARI, Wolaita-Sodo, Southern Ethiopia, Feb, 2017

Predictor variables		**Case**	**Control**	**COR (95% CI)**	**AOR (95% CI)**
Type of cooking fuels	Biomass fuel	265	736	**2.09 (1.29-3.39)**	**2.08 (1.03-4.22)**
	Mixed fuel	21	122	1.00	1.00
Cooking place	Inside the house	125	226	1.23 (0.73-2.08)	1.53 (0.85-2.76)
	Separate building	136	576	**0.52 (0.31-0.87)**	0.70 (0.39-1.26)
	Outdoor/open	25	56	1.00	1.00
Type of stoves usually used	Open stove	258	692	2.21 (1.44-3.38)	1.04 (0.61-1.75)
	Improved stove	28	166	1.00	1.00
House ventilation	Poor	186	288	**4.62 (2.92-7.30)**	**4.31 (2.60-7.15)**
	Moderate	75	391	1.37 (0.84-2.23)	1.57 (0.92-2.68)
	Good	25	179	1.00	1.00
Windows of the house	No window	22	42	**1.95 (1.04-3.66)**	0.77 (0.32-1.84)
	1 window	159	349	**1.70 (1.13-2.55)**	0.71 (0.36-1.38)
	2 windows	67	325	0.77 (0.49-1.20)	**0.51 (0.28-0.91)**
	3+ windows	38	142	1.00	1.00
Rooms in the house	1 room	118	229	**2.18 (1.53-3.11)**	1.46 (0.80-2.65)
	2 rooms	106	366	1.22 (0.86-1.74)	1.15 (0.69-1.90)
	3+ rooms	62	263	1.00	1.00
Child usually present during cooking	Yes	123	260	**1.73 (1.31-2.28)**	1.28 (0.92-1.77)
	No	163	598	1.00	1.00
Carrying child during cooking	Yes	106	202	**1.91 (1.44-2.55)**	1.65 (0.76-3.55)
	No	180	656	1.00	1.00
Family Cigarette smoking	Yes	11	11	**3.08 (1.32-7.18)**	1.84 (0.69-4.91)
	No	275	847	1.00	1.00
Mother Educational status	Illiterate	98	233	**1.40 (1.05-1.86)**	1.06 (0.76-1.49)
	Literate	188	625	1.00	1.00
Mother Employment status	Employed	30	180	1.00	1.00
	Petty trade	37	168	1.32 (0.78-2.24)	**0.50 (0.31-0.81)**
	Unemployed	61	124	**2.95 (1.80-4.83)**	**0.55 (0.36-0.86)**
	Housewife	158	386	**2.46 (1.60-3.77)**	1.12 (0.75-1.67)
Family size	≤5 Families	190	641	1.00	1.00
	>5 Families	96	217	**1.49 (1.12-1.99)**	**1.85 (1.30-2.61)**
Birth interval	<=2 Years	177	465	**1.37 (1.04-1.80)**	**1.40 (1.02-1.91)**
	>2 Years	109	393	1.00	1.00

* Bolded values are significant at p-value <0.05

6.2. PARTICULATE MATTER ($PM_{2.5}$) IN HAP (PAPER II)

Household air pollution measurement was conducted in to one hundred ten households, but one household's data was rejected due to the poor procedure of installing the monitoring device. Households were classified based on the type of fuels used for cooking. It was hard to find a house which used exclusively one type of fuel, the catagorization of type of fuel was based on the main/primary source of fuel as biomass fuel user and mixed type fuel. The mixed type of fuel includes both the solid fuel/ biomass and rarely electric stove users. Out of 109 households, 83 (76.15%) were biomass fuel users and 26 (23.85%) were mixed type fuel users.

6.2.1. Socio deographic characteristics

The type of fuel used for cooking was significantly associated at p-value <0.05 with mothers' education level, employment status of mothers', house ownership and monthly income of the household, while family size was not significantly associated with type of fuel used for cooking (Table 10).

Table 10. Sociodemographic variables and type of fuels for cooking, W/Sodo, Ethiopia, 2018

Sociodemographic variables (n=109)		Type of fuel for cooking		Total	Chi-squared
		Biomass	Mixed		(P value)
Education status	No Education	1 (4.8)	20 (95.2)	21 (19.3)	22.69
	Primary level	4 (11.1)	29 (88.9)	36 (33)	**(<0.001)**
	Secondary level	4 (20.0)	16 (80.0)	20 (18.3)	
	Higher level	17 (53.1)	15 (46.9)	32 (29.4)	
Employment status	Employed	13 (48.1)	14 (51.9)	27 (24.8)	12.31
	Petty trade	4 (18.2)	18 (81.8)	22 (20.2)	(**0.006**)
	Unemployed	4 (21.1)	15 (78.9)	19 (17.4)	
	Housewife	5 (12.2)	36 (87.8)	41 (37.6)	
Family size	<=5 Families	17 (22.7)	58 (77.3)	75 (68.8)	0.186
	>5 Families	9 (26.5)	25 (73.5)	34 (31.2)	(0.666)
Monthly income for the household	<1000 Birr	2 (6.3)	30 (93.7)	32 (29.4)	48.35
	1000-3000 Birr	3 (8.3)	33 (81.7)	36 (33)	**(<0.001)**
	3001-5000 Birr	5 (22.7)	17 (77.3)	22 (20.2)	
	>5000 Birr	16 (84.2)	3 (15.8)	19 (17.4)	
House ownership	Own house	21 (32.3)	44 (67.7)	65 (59.6)	6.33
	Rent house	5 (11.4)	39 (88.6)	44 (40.4)	**(0.012)**

The number of doors and windows of house, type of stoves, cooking place and level of ventilation were significantly associated with type of cooking fuels at p-value <0.05, while number of rooms, time spent in cooking and baking bread/injera were not significantly associated (Table 11).

Table 11. House and kitchen characteristics with types of stoves in W/Sodo, Ethiopia, 2018

House and kitchen variables (n=109)		Type of cooking fuels		Total	χ2 (P-value)
		Biomass	Mixed		
Number of rooms of the house	1 room	18 (90)	2 (10)	20 (18.3)	5.69
	2 rooms	32 (82.1)	7 (17.9)	39 (35.8)	(0.058)
	≥3 rooms	33 (66)	17 (34)	50 (45.9)	
Number of doors of the house	1 door	30 (93.7)	2 (6.3)	32 (29.4)	15.01
	2 doors	27 (84.4)	5 (15.6)	32 (29.4)	**(0.001)**
	≥3 doors	26 (57.8)	19 (42.2)	45 (41.3)	
Number of windows of the house	1 window	32 (94.1)	2 (5.9)	34 (31.2)	30.61
	2 windows	31 (93.9)	2 (6.1)	33 (30.3)	**(0.000)**
	≥3 windows	20 (47.6)	22 (52.4)	42 (38.5)	
Cooking place	Inside the house	37 (67.3)	18 (32.7)	55 (50.5)	4.81
	Separate kitchen	46 (85.2)	8 (14.8)	54 (49.5)	**(0.028)**
Type of stoves	Open stove	78 (89.7)	9 (10.3)	87 (79.8)	43.30
	Improved	5 (22.7)	17 (77.3)	22 (20.2)	**(0.000)**
Time spent in cooking	1 hour	12 (70.6)	5 (29.4)	17 (15.6)	3.47
	2 hours	49 (83.1)	10 (16.9)	59 (54.1)	(0.176)
	>=3 hours	22 (66.7)	11 (33.3)	33 (30.3)	
Baking injera	Yes	67 (74.4)	23 (25.6)	90 (82.6)	0.82
	No	16 (84.2)	3 (15.8)	19 (17.4)	(0.364)
Level of house ventilation	Poor	37 (97.4)	1 (2.6)	38 (34.86)	14.96
	Moderate	22 (68.7)	10 (31.3)	32 (29.35)	**(0.001)**
	Good	24 (51.5)	15 (38.5)	39 (35.77)	

* Bolded values are significant at p-value <0.05

The following pictures showing   the installation of measuring devices in different type fo stoves. Both are the traditional type of stoves which are very risky for exposure to the cook.

Figure 16. Installing position of UCB-PM device in a biomass fuel users houses, 2018

6.2.2. Level and characteristics of particulate matter

The study indicated that the average time monitored were 24.20 hours (SD=0.30). The Geometric mean concentration of $PM_{2.5}$ in all monitored households were 413.27 µg/m^3. The arithmetic mean of $PM_{2.5}$ in all monitored households were 772.03 µg/m^3 (SD=837.39) with 95% CI 613.04, 931.01. The magnitude of $PM_{2.5}$ were different for biomass and mixed type of fuel. The largest was biomass fuel users accounted to 926.34 µg/m^3 (SD=899.00) and followed by mixed type of fuel user, 279.42µg/m^3 (SD=216.71). The median concentration of $PM_{2.5}$ in all monitored households was 412.55µg/m^3. In the mixed type of fuel use, the electric stove users were contributed in reduction of household air pollution. One way ANOVA was analysed between fuel types, and found to be statistical significant resulted in differnt mean concentration of particulate matter for both type of fuels used in households [F(1, 107)=13.44, P=0.000] (Table 12).

Table 12. Average concentration of $PM_{2.5}$ ($\mu g/m^3$) in households W/Sodo, Ethiopia, 2018

Statistics (n=109)	**All fuels**	**Biomass**	**Mixed**
# of HHs (% of Total)	109(100%)	83(76.14%)	26 (23.9%)
Arithmetic Mean (SD)	772.03(837.39)	926.34(899.00)	279.42(216.71)
95% CI for the Mean	(613.04, 931.01)	(730.04, 1122.64)	(191.88, 366.95)
Geometric Mean	413.27	531.49	185.12
Median	412.55	589.97	230.90
Maximum	4161.82	4161.82	928.15
Minimum	5.50	5.50	5.50
Range	4156.32	4156.32	922.65
25^{th} Percentiles	189.15	240.82	117.07
75^{th} Percentiles	1085.94	1355.47	388.05
95^{th} Percentiles	2622.94	2821.37	823.36

A 24-hour Geometric mean $PM_{2.5}$ concentrations were presented in simple Boxplot Figure indicated the median, the inter-quartile range (the middle 50% of the data), lower and upper quartiles, the upper 25% and lower 25% of the data. Hence, it' s clear that the middle 50% of scores were more spread out for the biomass fuel user group than for those who used mixed type of fuels because the box is much longer. Within each box, there is a thick horizontal line, which shows the median. The biomass fuel users had a higher median than the mixed fuel users. The range of means was much wider for the mixed fuel users than the biomass fuel users (Figure 18).

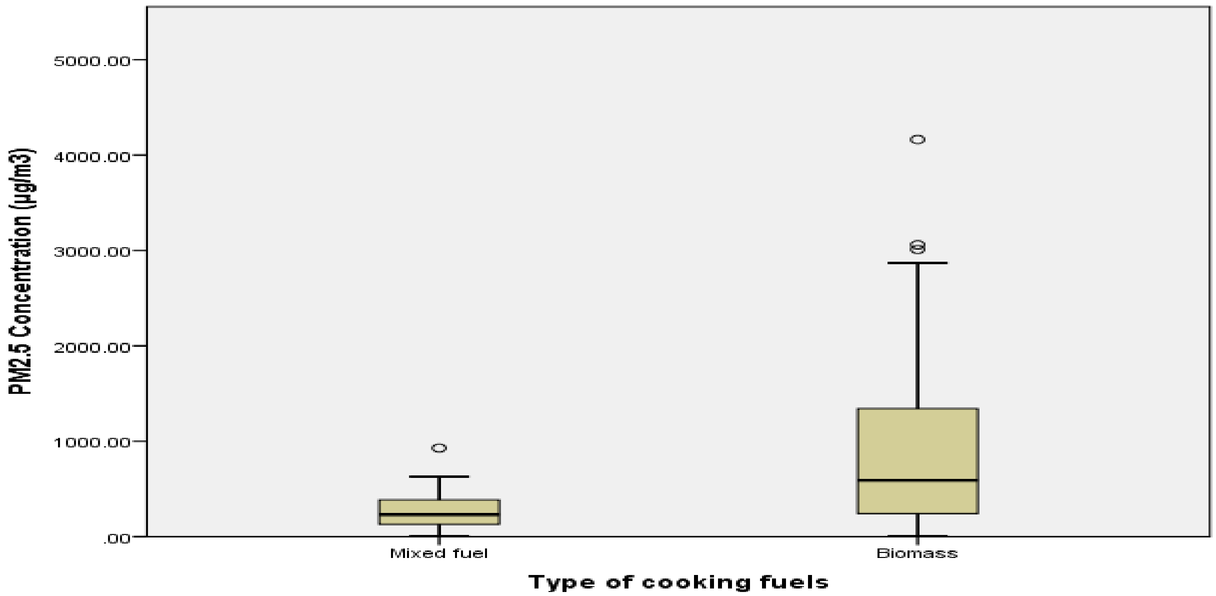


Figure 17. A Boxplot showing mean of $PM_{2.5}$ in and fuel types, W/Sodo, Ethiopia, 2018

The following graph shows household (biomass fuel user) the concentration of $PM_{2.5}$ in a 24 hour monitoring result presented in time frame. The peak concentration were cooking time for dinner (7:00pm-9:00pm local time). The second peak time was in the morning, breakfast time (7:00am-8:00am local time).

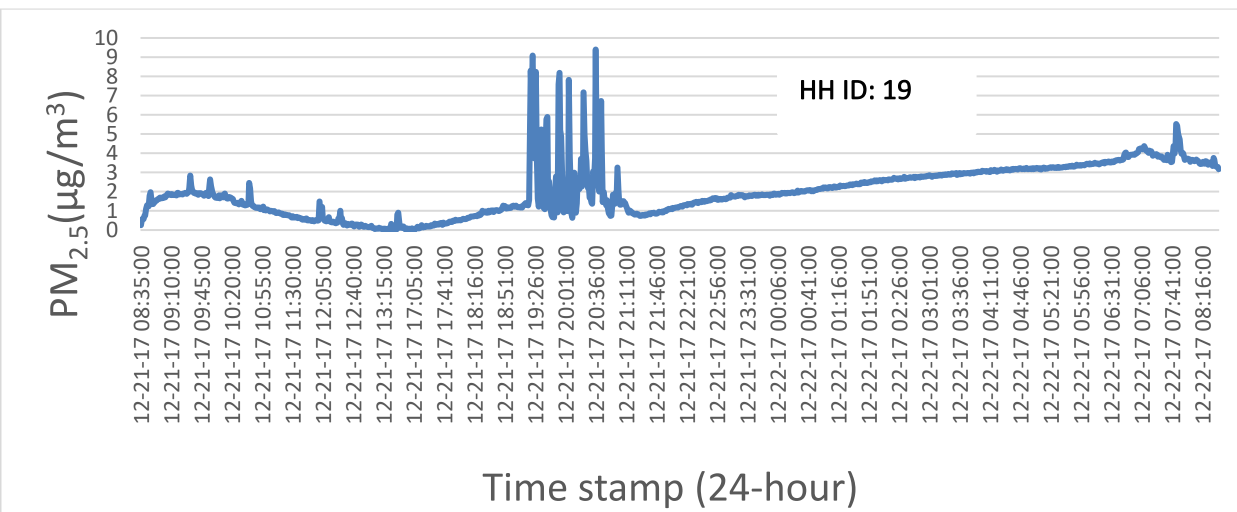


Figure 18. Level of $PM_{2.5}$ in a household using a biomass fuel during baking injera, 2018

The following graph shows household (mixed fuel users) the concentration of $PM_{2.5}$ in a 24 hour monitoring result presented in time frame. The peak concentration were cooking time for dinner (8:00pm-11:00pm local time). The second peak time was in the morning, lunch time (11:00am-01:30am local time). It is assumed to be biomass fuel use that makes peaks of concentrations.

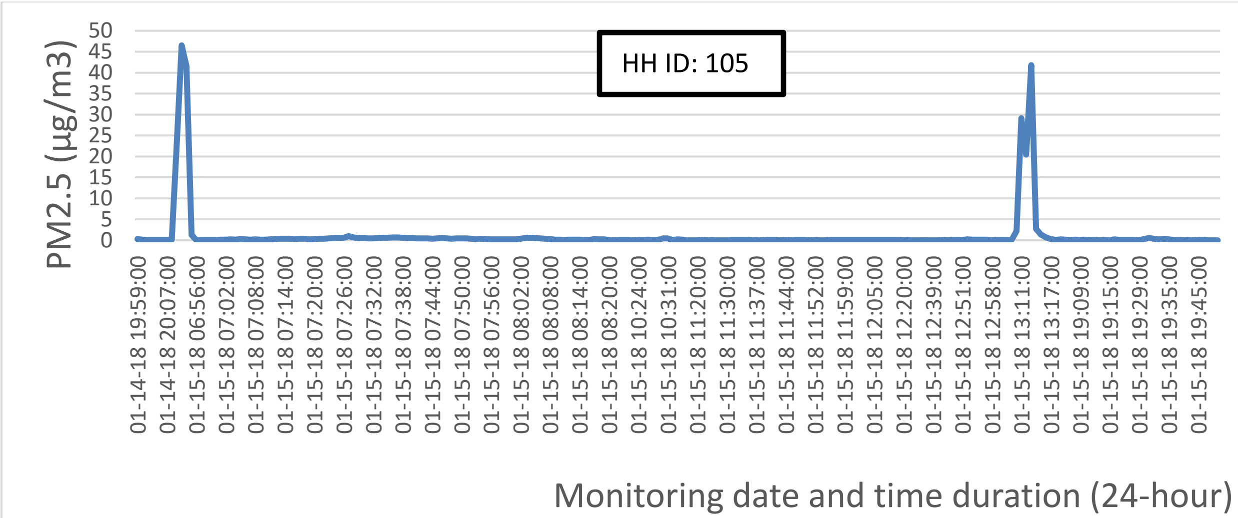


Figure 19. Level of $PM_{2.5}$ in a household using electric stoves for cooking, 2018

The 24 Hr. mean $PM_{2.5}$ concentrations were varied according to the number doors and windows of the house, it was least in the more than three doors and three windows houses than one door and one window houses, respectively. Those who used a separate kitchen for cooking showed slightly higher concentration of $PM_{2.5}$ than those who used inside the house. Improved stoves had lower emissions than the open stoves. Those who spent three hours or more in cooking indicated higher emissions of $PM_{2.5}$ than spending two hour or less in cooking. As to the level of house ventilation, adequately ventilated houses showed least emissions of $PM_{2.5}$ than moderately or poorly ventilated houses. The correlation test between variables and level of concentrations of particulate matter were analyzed using the "Eta statistics". If the Eta value is zero, it is indicating that no association between two variables, while if the Eta value is one, it indicates perfectly associated. The Eta square is to explain the level of concentration in terms of a given variable. Based on these, all variables were poorly associated with the level of particulate matter. Therefore, the Eta values for all variables were close to zero indicating which indicating no strong association between these variables (Table 13).

Table 13. A 24 hour- $PM_{2.5}$ ($\mu g/m^3$) and house/kitchen variables, W/Sodo, Ethiopia, 2018

House and kitchen variables		Total	$PM_{2.5}$ ($\mu g/m^3$)		Eta test	
			Mean	SD	Eta value	Eta square
Number of doors of the house	1 door	32	741.33	762.61		
	2 doors	32	983.82	1027.82	0.171	2.92%
	≥3 doors	45	643.25	718.94		
Number of windows of the house	1 window	34	754.37	743.59		
	2 windows	33	1038	1026	0.228	5.19%
	≥3 windows	42	577.02	695.44		
Type of fuel	Mixed	26	279.42	216.71	0.331	10.95%
	Biomass fuel	83	926.34	899.00		
Cooking place	Inside the house	55	653.77	775.37	0.143	2.04%
	Separate kitchen	54	892.47	887.18		
Type of stoves	Open-fire stove	87	873.41	893.05	0.242	5.85%
	Improved/electric	22	371.11	359.46		
Time spent in cooking	1 hour	17	732.53	772.75		
	2 hours	59	772.68	843.67	0.023	0.0%
	≥3 hours	33	791.20	881.34		
Level of house ventilation	Poor	38	904.56	959.26		
	Moderate	32	793.81	735.62	0.142	2.01%
	Good	39	625.02	784.47		

6.3. CARBON MONOXIDE IN HAP (PAPER III)

6.3.1. Socio deographic characteristics

The concentration of CO was monitored in 66 households, but 11 household measurements were discarded for poor quality data. Among 55 households, biomass fuel users, 45 (81.8%) and mixed type fuel user household were 10 (18.2%). The type of fuel used for cooking was significantly associated at p-value <0.05 with only to monthly income of the household and house ownership, while the rest sociodemographic variables were not significantly associated with type of fuel used for cooking (Table 14).

Table 14. Sociodemographic variables and type of fuels for cooking, W/Sodo, Ethiopia, 2018

Sociodemographic variables		Types of fuel for cooking		Total	$\chi 2$
		Mixed	Biomass		(P-value)
Mother education status	No Education	-	10 (100)	10(18.2)	8.617
	Primary level	3(14.3)	18(85.7)	21(38.2)	**(0.035)**
	Secondary level	1(10)	9(90)	10(18.2)	
	Higher level	6(42.9)	8(57.1)	14(25.5)	
Employment status of mother	Employed	5(41.7)	7(58.3)	12(21.8)	5.896
	Petty trade	1(8.3)	11(91.7)	12(21.8)	(0.117)
	Unemployed	1(10)	9(90)	10(18.2)	
	Housewife	3(14.3)	18(85.7)	21(38.2)	
Family size	<=5 Families	7(16.7)	35(83.3)	42(76.4)	0.013
	>5 Families	3(23.1)	10(76.9)	13(23.6)	(0.911)
Monthly income for the household	<1000 Birr	1(5.6)	17(94.4)	18(32.7)	20.890
	1000-3000 Birr	1(6.3)	15(93.7)	16(29.1)	**(<0.001)**
	3001-5000 Birr	2(15.4)	11(84.6)	13(23.6)	
	>5000 Birr	6(75)	2(25)	8(14.5)	
House ownership	Own house	9(29)	22 (71)	31(56.4)	4.075
	Rent house	1(4.2)	23(95.8)	24(43.6)	**(0.044)**

The type of fuel used for cooking was significantly associated at p-value <0.05 with number of windows of the house, type of stoves used and time spent in cooking. Other variables were not significantly associated with type of fuel used for cooking (Table 15).

Table 15. House and kitchen characteristics with types of stoves in W/Sodo, Ethiopia, 2018

House and kitchen variables		Type of fuel for cooking		Total	χ^2
		Mixed	Biomass		(P-value)
Number of rooms of the house	1 room	1 (7.7)	12 (92.3)	13 (23.6)	2.001
	2 rooms	3 (15.8)	16 (84.2)	19 (34.5)	(0.368)
	≥3 rooms	6 (26.1)	17 (73.9)	23 (41.8)	
Number of doors of the house	1 door	1 (4.5)	21 (95.5)	22 (14)	5.142
	2 doors	3 (21.4)	11 (78.1)	14 (25.5)	**(0.076)**
	≥3 doors	6 (31.6)	13 (68.4)	19 (34.5)	
Number of windows of the house	1 window	1 (4.5)	21 (95.5)	22 (40)	9.13
	2 windows	1 (8.3)	11 (91.7)	12 (21.8)	**(0.010)**
	≥3 windows	8 (38.1)	13 (61.9)	21 (38.2)	
Cooking place	Inside the house	7 (24.1)	22 (75.9)	29 (52.7)	0.739
	Separate kitchen	3 (11.5)	23 (88.5)	26 (47.3)	(0.390)
Type of stoves	Open stove	4 (8.5)	43 (94.5)	47 (85.5)	24.638
	Improved stove	6 (75)	-	8 (14.5)	**(<0.001)**
Time spent in cooking	1 hour	1 (11.1)	8 (55.6)	9 (16.4)	8.828
	2 hours	2 (6.9)	27 (65.5)	29 (52.7)	**(0.012)**
	>=3 hours	7 (41.2)	10 (11.8)	17 (30.9)	
Level of house ventilation	Poor	-	21 (100)	21 (38.2)	7.618
	Moderate	5(27.8)	13 (72.2)	18 (32.7)	**(0.022)**
	Good	5(31.3)	11 (68.7)	16 (29.1)	

* Bolded values are significant at p-value <0.05

6.3.2. Level characteristics of carbon monoxide

The 24 hour measurmnet of mean concentration of CO in all monitored households were 14.26 mg/m^3 (SD=10.06) with 95% CI of Mean 11.54, 16.98. The magnitude of CO were different for different fuel sources, which was the larger in biomass fuel users accounted to 14.41mg/m^3 (SD=10.29) and followed by mixed type of fuel user, 13.55 mg/m^3 (SD=9.41). The Geometric mean and median concentration of CO in all monitored households were 11.51 mg/m^3 and 9.57 mg/m^3 respectively. One way ANOVA was analysed between fuel types, and found to be not statistical significant resulted more or less similar mean concentration of carbon monoxide between both type of fuels used in households [$F(1, 53)=0.059$, $P=0.809$]. (Table 16).

Table 16. Average magnitude of 24 hr CO (mg/m^3), in households of W/Sodo, Ethiopia, 2018

Statistics	**All fuels**	**Biomass**	**Mixed**
# of HHs (% of Total)	55(100%)	45 (81.8%)	10 (18.2%)
Arithmetic Mean (SD)	14.26(10.06)	14.41(10.29)	13.55(9.41)
95% CI for the Mean	11.54, 16.98	11.32, 17.51	6.82, 20.29
Geometric Mean	11.51	11.57	11.25
Median	10.73	10.71	11.09
Maximum	42.37	42.37	36.47
Minimum	4.58	4.58	4.59
Range	37.79	37.79	31.88
25^{th} Percentiles	6.83	6.95	6.07
75^{th} Percentiles	19.76	20.13	16.82

A 24 Hr. mean CO concentrations were presented in boxplot indicated the median, the inter-quartile range (the middle 50% of the data), lower and upper quartiles, the upper 25% and lower 25% of the data. Hence, it' s clear that the middle 50% of scores were more spread out for the biomass fuel user group than for those who used mixed type of fuels. Within each box, there is a thick horizontal line, which shows the median, in this case it was similar in both type of fuels. The biomass fuel users had a higher median than the mixed fuel users. The range of means was much wider for the biomass fuel users than the mixed fuel users (Figure 21).

Figure 20. Mean of CO in different fuel types for cooking, W/Sodo, Ethiopia, 2018

In the households monitored for carbon monoxide with different fuel use category showed that, significant level of CO was measured. In the mixed fuel type users: the graph showed few peaks which could be resulted from biomass fuel or other smoke emitting activities. The time where no peaks could be either from no cooking time or using improved/electric fuels for cooking. Similarly, in primarily charcoal and wood fuel users, the number of peaks is too much indicating that the emission level was higher as compared to mixed type of fuels (Figure 22).

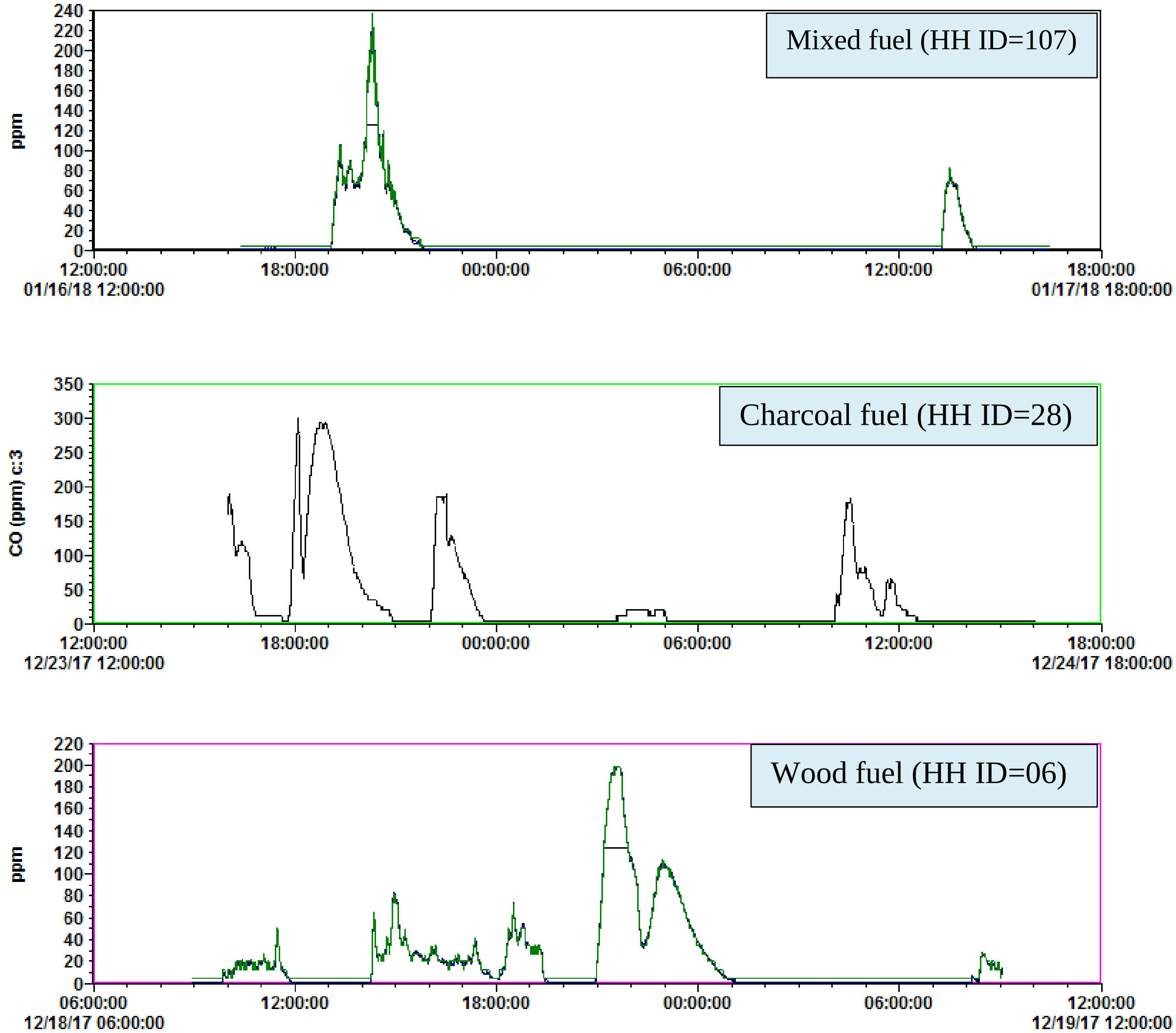


Figure 21. Level of CO in households using different fuels for cooking, 2018

The 24 Hr. mean CO concentrations were varied according to the number rooms and windows of the house; it was highest in the one room, one window and one door houses than the two or more rooms, windows and doors houses respectively. Those who used a separate kitchen for cooking were showed slightly lower concentration of CO than those who used inside the house. Open stoves and mixed fuel users had no significant difference in emission of CO. Those who spent one hour in cooking indicated higher emissions of CO than spending two hour or more hour in cooking. As to the level of house ventilation, adequately ventilated houses showed least emissions of CO than moderately or poorly ventilated houses (Table 17).

Table 17. A 24hr CO (mg/m^3) and house/kitchen variables, W/Sodo, Ethiopia, 2018

House and kitchen variables		Total	CO level (mg/m^3)	
			Mean (SD)	Median
Number of rooms of the house	1 room	13	20.09 (12.34)	20.44
	2 rooms	19	11.42 (6.29)	10.26
	3+ rooms	23	13.31 (10.24)	10.61
Number of doors of the house	1 door	22	16.97 (10.91)	11.40
	2 doors	14	11.51 (7.10)	10.00
	3+ doors	19	13.14 (10.58)	10.04
Number of windows of the house	1 window	22	16.33 (11.14)	10.96
	2 windows	12	11.43 (5.64)	10.67
	3+ windows	21	13.71 (10.74)	10.04
Cooking place	Inside the house	29	15.89 (11.07)	11.20
	Separate kitchen	26	12.44 (8.65)	9.82
Type of stoves	Open-fire stove	47	14.40 (10.07)	10.73
	Improved/electric	8	14.23 (11.23)	10.04
Time spent in cooking	1 hour	9	17.63 (13.44)	11.45
	2 hours	29	13.78 (9.86)	10.26
	>=3 hours	17	13.28 (8.55)	10.73
Level of house ventilation	Poor	21	15.20 (11.02)	11.06
	Moderate	18	15.92 (9.13)	12.04
	Good	16	11.15 (9.65)	6.79

6.4. REVIEW OF MAIN FINDINGS OF THE DISSERTATION

Table 18. Summary of main findings of this PhD dissertation, 2019

Papers	Main findings
I	• Three-fourth of children lived in households used biomass fuels (87.5%). • The majority of households (83%), used open-fire/traditional three stone stoves. • The prevalence of ARI in under-five children was 10.1% (95% CI 9.5, 10.8). • Biomass fuel users for cooking (AOR=2.08, 95% CI 1.03-4.22), poorly ventilated houses (AOR=4.31, 95% CI 2.60-7.15), less than 2 years of child birth interval (AOR=1.41, 95% CI 1.03-1.92), large family size, (AOR=1.85, 95% CI 1.30-2.61), petty trade job mother (AOR=0.50, 95% CI 0.31-0.81) were significant risk factors of acute respiratory infection in under five children.
II	• 83 (76.15%) were biomass fuel users and 26 (23.1%) were mixed fuel users. • The Geometric mean concentration of $PM_{2.5}$ in all monitored households were 413.27 µg/m^3. The arithmetic mean was 772.03 µg/m^3 (SD=837.39). • The magnitude of $PM_{2.5}$ were different for different fuel sources, which was the higher in biomass fuel users accounted to 926.34 µg/m^3 (SD=899.00) and mixed fuel users which accounted to 279.42µg/m^3 (SD=216.71). • The median of $PM_{2.5}$ in all monitored households was 412.55µg/m^3. • The higher contribution of PM in the households was dominantly by biomass fuel users than the mixed type fuel users.
III	• The 24-hour mean of CO in all households were 14.26 mg/m^3 (SD=10.06) with (95% CI of Mean 11.54, 16.98). • The magnitude of CO was different for different fuel sources, which was the higher in biomass fuel users accounted to 14.41mg/m^3 (SD=10.29) and followed by mixed fuel user, 13.55 mg/m^3 (SD=9.41). • The GM and median of CO were 11.51 mg/m^3 and 10.73 mg/m^3 respectively. • The correlation coefficient between the concentration of CO and $PM_{2.5}$ were 0.075, but after controlling of types of biomass fuel used in the houses, the partial correlation coefficient was 0.199, indicating that the level of CO and $PM_{2.5}$ were not dependent of each other

7. DISCUSSION

The dissertation investigated the link between household air pollution particularly from biomass cooking fuel and acute respiratory infection in under five children in the community based study. Thus the study showed that, children living in a poorly ventilated houses and using biomass fuel for cooking were affected by acute respiratory infection. Moreover, households using biomass fuel for cooking were reported to higher pollution level of particulate matter ($PM_{2.5}$) and carbon monoxide, which is much exceeds the WHO AQG values.

7.1. BIOMASS COOKING FUELS AND ARI IN CHILDREN

Acute respiratory infection continues to be the leading cause of acute illness worldwide and remain the most important cause of infant and young children mortality (98). Similarly, acute respiratory infection in children contribute the leading mortality and morbidity among under five children in Ethiopia. The current study supports this evidences with the prevalence of the acute respiratory infection in the study area was reported 10.1% (95% CI 9.5, 10.8). This report showed that higher than the EDHS 2016 report, 7% (22), and lower than the India study with cross sectional design, prevalence of ARI was found to be 27% (99), in a peri-urban area of Delhi, a prospectively study showed the overall 2-week prevalence of all types of ARI was 34.3% (100). In the latter two studies, the sample size were very limited and studied in a cohort of studies.

Health impact assessments of different air pollution source contributions are important for finding the most effective abatement measures (41). However, many factors associated with acute respiratory infections, only fews were explored in this dissertation. Biomass fuel is chief sources of fuel by almost all participant households' in this study. In this study, the main type of cooking fuel in the household were analyzed against children ARI. Biomass fuel users showed a significant effect on children ARI as compared to mixed fuels (electricity, biogas, LPG and biomass fuels) users for cooking. This study result was in line with previous studies, biomass cooking fuel was significantly associated with acute lower respiratory tract infection in India (OR 4.73, 95% CI 1.67–13.45) (70), the incidence of ARI was higher in children living in houses where biomass fuel was used for cooking (RR 1.5, 95% CI 1.2-1.9) (76) and a study of systematic review and meta-analysis, the overall pooled odds ratio of unprocessed fuel use and risk of pneumonia was (OR 1.78, 95% CI 1.45–2.18) (101). Generally, children from biomass fuel user households were more likely to suffer from ARI than mixed type of fuel users. The reason could be biomass fuel emit small sized particulate matter which able to deposit in the lungs. Later, deposited particulate matters may alter airway reactivity to antigens or affect the ability of the lungs to handle bacteria, suggesting that exposure may result in enhanced susceptibility to microbial infection (4). This implies that if children have exposed to biomass and charcoal fuel, they would have higher chance of getting ARI.

Most developing countries, use stones, bricks, concrete, and cement to build their houses, most houses rely on natural ventilation through open windows and shutters. The poor socioeconomic strata of society in these countries continue to live in ill-ventilated and ill-lit houses made of bamboo, wood, crop residues, tin sheets, and sometimes cloth. This in turn has affected the quality of the finished housing, leading to an overall poor quality of housing (102).

The number of doors and windows are pertinent in improving house ventilation and also associated with children ARI. The odds of ARI in children who are living in poorly ventilated houses were four times higher than living in houses who had good ventilation houses. This study was consistent with the study conducted in slum areas of Addis Ababa, with odds ratio of 2.96 (95% CI: 1.38-3.87) in their study houses (51). This indicated that smokes from a poorly ventilated houses could lead to higher chance of exposing the child.

A study in Rwanda to investigate the role of the microenvironment as a determinant of children's HAP-related health symptoms showed that a strong positive association between group of multiple enclosed dwellings, relative to single house, and under-five children HAP-related symptoms (respiratory infection, difficulty breathing and dry eyes) experienced in the past 2 weeks (103).

Household's family size or crowding is a proxy for the respiratory infection in children, hence the odds of ARI in children were twice higher in households with higher crowding (family members). The result of this study was in agreement with the study done in central India, that 53.2% of cases with history of overcrowding in family had a high risk of ARI compared to the control group 22.8% ($p < 0.0001$, OR = 3.84) (98), in Nigeria, a family size of more than 5 siblings living in a home was shown to affect significantly the prevalence of pneumonia (104), and a systematic study with meta-analysis revealed that, crowding of a house (more than 7 persons in a household or more than 2 persons per room) is a risk factor for severe acute lower respiratory infection (71). The implication of these evidences that where large family size posed a crowding of house that could influence the health of the house members particularly, children with high probability of the transmission of droplets of infective organisms due to overcrowding.

However, it is found that the type of floor materials in the kitchen, chimney in kitchen and time spent in cooking had no a significance relation with acute respiratory infection of the child. This could be due to the lack of detail measurement procedure, inpropre enemueration of time spent in cooking and the proper functionality of the chimney.

7.2. THE LEVEL OF PARTICULATE MATTER ($PM_{2.5}$) IN HAP

Household air pollution is explained by the presence of pollutants in the house with sufficeint amount that causes risk to the health of inhabitants. There are at least sixty sources of household air pollution, and these vary from country to country (102). This section of the dissertation discusses the concentration of particulate matter in the houses in a measurement of 24 hour duration. The overall geometric mean of the of $PM_{2.5}$ in Wolaita Sodo town households was 413.27 $\mu g/m^3$. The arithmetic mean (SD) concentration of $PM_{2.5}$ in Wolaita Sodo town households were 772.03 $\mu g/m^3$(837.39). The magnitude of $PM_{2.5}$ were different for different fuel sources, which was the highest in biomass fuel users, 531.49$\mu g/m^3$ and mixed fuel users, 185.12$\mu g/m^3$.

According to the WHO Air Quality Guidelines recommendation, $PM_{2.5}$ for 24 hour Geometric mean level in houses should not exceed 25 $\mu g/m^3$ (2, 54), WHO Interim Target-1 (IT-1) is 75$\mu g/m^3$, WHO Interim Target-2 (IT-2) is 50 $\mu g/m^3$ and WHO Interim Target-3 (IT-3) is 37.5 $\mu g/m^3$ (2, 54). Our study result indicated excessively higher than the WHO air quality guideline values and the WHO IT-1, IT-2 and IT-3 values. Domestic household air quality levels associated with biomass fuel combustion in Nepal exceed WHO Household Air Quality standards and are in the hazardous range for human health (11). The geometric mean concentration level of biomass fuel users was 531.49$\mu g/m^3$, which was twenty-one times higher than the WHO AQG values of a 24 hour mean level, and the mixed type of fuel users were 185.12 $\mu g/m^3$, which was seven folds higher than the WHO AQG values for a 24 hour mean level.

The current study was compared with the study conducted in Shero-Meda sub city of Addis Ababa, Ethiopia revealed that the 24-hour particulate matter levels in the kitchens at an average of 1580 $\mu g/m^3$ with a Geometric mean (SD) 793.38 (1580) $\mu g/m^3$, all households exceeded the United States Environmental Protection Agency standard of 35 $\mu g/m^3$ (52), the Shiro-Meda area in Addis

Ababa is known to use biomass fuels (particularly tree leaves which has higher smoke and the communities area low living standard as compared to other areas in the city. Similar study showed in Ethiopia (Bonga and Kebribeyah refugee camps), the 24 hour $PM_{2.5}$ were 1250 μg/m^3 (55). The reason could be, Bonga and Kebribeyah are refugee camps which could use non-clean fuels (biomass fuels) exclusively for cooking. Our measurements of a 24 hour particulate matter ($PM_{2.5}$) were compared with local study conducted in slum neighbor hoods of Addis Ababa city, indicated that the geometric mean were 818μg/m^3 (Solid fuel=1134μg/m^3, kerosene=637μg/m^3 and clean fuel=335μg/m^3) (50).

A state and national household concentrations from solid cook fuel use in India, a mean level were ranged from 163 μg/m^3 in the living area to 609 μg/m^3 in the kitchen area (45). The justification for being higher concentration in these study areas were due to the study period, sample size, socioeconomic and type of devices measured in different areas. In the previous periods particulate matter in general household air pollution were expected to be higher than the current, since the urbanization and modernization leads to the use of clean fuel sources for cooking purpose. However, the study setting in India was a state and national level which hardly to compare with the current study. But, our study had slightly lower emissions as compared to a study in rural Ghana households cooking with biomass fuels a mean were 446.8 μg/m^3 (68), it can be explained that, however Ghana is considered more developed than Ethiopia, and but this study was conducted rural setting and in a small sample size at 36 households.

A research conducted in Peru showed that the type of fuel used to cook had a significant effect on kitchen concentrations of $PM_{2.5}$ in Peru (105). This indicating that the study area used other fine particulate matter emitting activities and may use polluting fuels exclusively the study area was more populated and living in slum areas.

In a similar study, significantly higher concentration were reported in rural village of district Jhajjar of Haryana state, India to predicting exposure levels of respirable particulate matter ($PM_{2.5}$) for the cook from combustion of cooking fuels in a 24 hr measuriment indicating a varied concentration from 4.69 μg/m^3 for gas/LPG stove to 11000 μg/ m^3 for dung cake/Chulah (106), but separately for the gas, wood/chulah, the crop residue/chulah, dung cake/challah and mix fuel/chulah was 25.67 μg/m^3, 222.69 μg/ m^3, 393.39 μg/ m^3, 774.52 μg/m^3 and 376.40 μg/ m^3 respectively. The discrepancy was extremely large as compared to our study with the maximum reported concentration was 2408.30 μg/ m^3 for the biomass fuel. This could be due to the fact that Indian communities were more rural setting than our study settings. Moreover, in our study, dung cake was not a primary fuel source, which has a potential to emit large concentrations of particulate matter as compared to other biomass fuel sources since our study is in a semi urban setting. Similarly, our study was reported lower concentration than the Modeling study of household air pollution from cook stove emissions in developing countries using a Monte Carlo single-box model, the mean modeled 24 hour concentration for $PM_{2.5}$ was 1975 μg/m^3 (median=1320 μg/ m^3) (107). This modeling was not a direct method of measuring particulate matter concentration, instead it used a proxy factors to estimate approximate measurements. Hence, it could have significant variations with the actual measurement.

7.3. THE LEVEL OF CARBON MONOXIDE HAP

The level of CO in households an indicator of exposure and an indicator of health risk factors (46). The mean concentration of CO in Wolaita Sodo town households were 14.26 mg/m^3 (SD=10.06). The magnitude of CO were different for different fuel sources, which was higher in biomass fuel users 14.41 mg/m^3 and followed by mixed fuel users, 13.55 mg/m^3.

According to the World Health Organization guidelines for indoor air quality (IAQ) recommendation, CO for 24 hour mean concentration in houses should not exceed 7 mg/m^3 (53, 108), WHO also suggests of carbon monoxide for 8 hour exposure should not exceed above 10 mg/m^3 (53, 108). Our study result indicated that carbon monoxide was twice higher than the WHO IAQ guideline in the monitored houses. This indicating that the study area used other carbon monoxide emitting activities, such as tobacco smoke, incense and exhaust of motor vehicle from outside environment. The study households could be using charcoals as their alternate choice of fuel where electric fuel was not available, as charcoal is a known emitting source of carbon monoxide. Similarly, estimated area CO concentrations in biomass smoke in Burkina Faso were also very high. The mean 24-h concentration reported in 119 households was 16.9 ppm (95 % CI 12.3–21.4 ppm) (61).

In Bonga and Kebribeyah refugee camps of Ethiopia, a study was undertaken to assess the potential of two types of improved cook stoves to reduce household air pollution, the 24 hour CO were 38.9 ppm (≈44.54 mg/m^3) (55), which was significantly three times higher than the current study. The reason could be, in the previous studies, since Bonga and Kebribeyah study areas were refugee camps, the dominant cooking fuels could be biomass, while the current study setting was apparently urban. Similarly, the average 48 hour measurement of CO kitchen concentration in the charcoal and kerosene stove case were reported to 28.2 mg/ m^3 in a Clean Cook Stove Tests in Addis Ababa, Ethiopia (109), which was twice higher than the current study, the reason could be the Addis Ababa study was exclusively on charcoal and kerosene stoves and expected to be higher concentration of CO. Another study was conducted in one of the most common practice of the coffee ceremony in Ethiopia showed that particulate matter and carbon monoxide exposures for both preparers and participants were increases, and these increases exceeded the WHO exposure guidelines (110), because charcoal is the primary choice of fuel sources in coffee ceremony, in Ethiopia.

The CO concentration were compared with previous studies across the world, and the mean 48-h kitchen CO concentration in 60 homes of Michoacan, Mexico with the traditional fogon was 8.2 ppm (≈9.39 mg/m^3) (35); in Palwal District of Haryana, India, a 24-hour personal CO concentrations were 5.27 ppm (≈6.03 mg/ m^3) (44), which was lower than the current study. The possible justification might be the personal exposure measurement is slightly lower than the household air measurement. Daily average CO concentrations collected in area near stove were 10.9 (10.5–11.3) ppm among households with traditional cookstoves in Southern Nepal in cookstove intervention trial study (111). Similarly, in study conducted in a three poor resource setting countries, Peru, Nepal and Kenya, revealed that household CO concentrations were in a safe range(<7 ppm) for 64%, 79%, and 46% of the time in Peru, Nepal, and Kenya, respectively (14).

Fortunately, there are studies which showed similar level of CO, in Ghana, a study was undertaken to assess the potential of two types of improved cookstoves to reduce household air pollution, the 24 hour CO concentration were measured to be 12.3 ppm (≈14.08 mg/ m^3) (55). Similarly, a study conducted in Ghana, to examine the cooking practice in kitchen revealed that the concentration of CO was 14.5 mg/m^3 (95% CI 12.0, 16.9) (68).

Strong area PM_{10} and area CO correlations were found with household kitchens (Spearman's rho=0.82, $p<0.0001$) (61), but this correlations were very weak in the current study (Spearman's rho=0.12, p= 0.359). The weaker correlation observed between $PM_{2.5}$ and CO level in the current study was due to lack of seasonal and fuel specific comparisions, lack of testing using different settings and environment, and lack of non cooking time measurement.

In general, the results of this dissertation has been compared with previously conducted studies, all over the world. The literature mostly from developing world, like India. But the study setting and methodology was similar. It was hard to find local litratures with rarely conducted researches in Ethiopia. The overall out come of this research supports the existing evidences which had been done in the globe.

8. VALIDITY AND GENERALIZABILITY

This part of the study describes the issue of validity and generalizability of this study. Validity means the degree to which an inference, conclusion or measurement corresponds precisely to the real world and gives best possible approximation of its truth. Validity of an instrument refers to its ability to measure the right elements that are needed to be measured, while generalizability refers to the 'applicability' of any research findings of the study can be applied to the larger samples or populations. The validity and generalizability of a research determined by the quality of study protocol, ease of application, feasibility of procedures, the quality of data collectors and supervisors. Poor quality of study protocol leads to naive result outcome, which leads to less valid data and hasty generalization.

Internal validity: Internal validity is normally affected by flaws in the study like not controlling some of the major variables or any problems with the research instrument. The finding of this study was explained through the methods, procedures and analysis of the study in the actual processes. Although research processes, chances, biases and errors were more likely to happen in the study, their management to ensure data quality is described below. Households and participants were selected based on the systematic sampling techniques and in a random base. Data collection instruments were used and applicable for the specific purposes in other similar settings, data collection tools were pretested before the actual data collection. Cases and controls were identified based on the standard WHO classification criteria. Cases were identified by the independent assessment of the data collectors and supervisors. HAP monitoring devices were commonly used devices all over the world and a product of University of California Barkeley, USA. Its consistencies were checked each other and with other gold standard monitoring devices. The consistency level was reported to higher level of Cronbatch alpha. Multicollinearity test were checked for collinearity of variables, and finally, multivariable analysis was run in two objectives to control the confounding variables.

Chance: Chance is a random error appearing to cause an association between an exposure and an outcome. The role of chance (random error) in this study was minimized by properly designing tools and procedures of the study protocol. Training manual was prepared. Operational definitions and concepts were defined. Adequate sample size was randomly assigned to each specific objective. Surveys and instrumental monitoring of HAP were conducted using SOPs and strict supervisions, hence the error encountered through measurement were reduced. Cases and controls were not only determined by the data collectors but also reconfirmed by the supervisors in the field too. This reduced a false positive and false negative results in the case control study objective.

Bias: Bias is any systematic error in a research methodology that results in an incorrect estimate of the association between exposure and outcome. Child's size was determined based on the mother's response which potentially increases the size of their child because of social desirability bias. We controlled such bias with cross checking methods, cards, comparisons with their previous born children and other family witnesses. Observational checklist for the characteristics of houses and kitchen minimized the bias about the responses of participants.

Selection bias: Selection bias is the bias introduced by the selection of individuals, groups or data for analysis in such a way that proper randomization is not achieved, thereby ensuring that the sample obtained is not representative of the population intended to be analyzed. In this study, Kebeles were selected randomly with assumption of homogenous characteristics. Census was conducted in these Kebeles to enumerate number of children and eligible households to set a sampling frame. Sample sizes were allocated based on probability proportional to size of the households which were eligible to size. Households were selected using systematic sampling method. If there were two under five children in the same house, one child was selected randomly using lottery method. Households for HAP monitoring were also selected in systematic random sampling techniques.

Information bias: Information bias results from systematic differences in the way data on exposure or outcome are obtained from the various study groups. This could be observer bias, losses to follow up and recall bias. In this study information bias were reduced through development of a protocol for the data collection, measurement and interpretation of information, use of standardized questionnaires (adapted from WHO and EDHS household servey tool) and training of interviewers. House code were used to identify the houses during the HAP monitoring and losses to follow up were not a problem. SOPs, instrument protocol and training manual were used to minimize the error related to measurement of HAP. Study results were compared primarily with WHO and USEPA household air quality standards. Family members were involved in recalling a two weeks period health status of her child besides the mother.

Possible sources of errors in the study: The child health outcome, i.e. cases and controls were identified based on the mother's response only, this will introduce measurement bias. Other possible source of error was place of delivery, their age and monthly salary. Most mothers were genuine to respond about their place of delivery. They likely responded to say health facility delivery. These were the possible sources of errors in the study.

External validity (generalizability): describes the extent to which research findings can be applied to settings other than in which they were originally conducted. Since, confounding factors were managed using a multivariable logistic regression in a hierarchal model, the level of pollution was triangulated by survey, pollution level measurement and activity pattern assessment, two types of pollutants (particulate matter and carbon monoxide) were monitored, the study was conducted in semi-urban setting which considered both the rural and urban settings, interview tools were standardized and tested, HAP monitoring tools were checked it consistencies; and validated with other gold standard devices, HAP data were analyzed in a software designed to its purpose, the results of this study will be generalized to similar settings to develop action plan, local guidelines and management tools efficiently.

9. STREANGTHS AND LIMITATIONS

The study was conducted on large sample size, which could help to make a plausible conclusion. Cases and controls were selected based on the WHO classification criteria of acute respiratory infection in children. The research team tried to operationalize variables, used appropriate and professional data collectors, supervisors, and used a cross checking with different persons to classify cases and controls. HAPs, ($PM_{2.5}$ and CO) wer measured for longer period (24-hour) duration, which provides valid data, HAP devices were check its validity with co-located gold standard measurement (gravimetric) devices.

However, this research also might have suffered a recall bias, as case control studies are inherent with this type of bias. It was difficult to separate households based on their type of fuel use, because of no households used exclusively on single fuel source. The study lacked individual exposure measurements of specific particulate matter, carbon monoxide and unable to link the health outcome with concentration of these pollutants. The study also unable to recognize the seasonal variability of the HAP measurement due to a one-time measurement only. The study lacked outdoor measurement, which could affect the indoor air.

10. CONCLUSIONS AND POLICY IMPLICATIONS

10.1. Conclusions

Objective I:

- Primary energy source for cooking in the study area (8.7 in 10 households) use biomass fuel for cooking.
- This study explored nearly, one in ten under five children were identified with ARI case.
- Biomass fuel sources had an effect on acquiring of ARI.
- Poorly ventilated houses, houses with no windows, less than 2 years of childbirth interval, unemployed mother and child living with a family of more than five were risk factors for the development of child ARI.

Objective II and III

- Regarding HAP, the concentration of $PM_{2.5}$ and CO were much more exceeded than the WHO AQG values and USEPA.
- $PM_{2.5}$ and CO emissions in our study were slightly lower than other similar studies; the overall concentration is generally unacceptable.
- The type of fuel use, type of stove use and longer time spent in cooking was statistically significant with high emissions of $PM_{2.5}$.
- Similarly, lower number of rooms, doors and windows of the house, biomass fuel use, cooking inside the house and poorly ventilated houses recorded higher concentration of CO in the house.

10.2. Policy and program implications

The Federal Democratic Republic of Ethiopia constitution states “the right to clean and healthy environment to peoples, hence, environmental and pollution control proclamations, housing policy, energy supply policy and health policy are established, however household air pollution is not addressed in each policies. Currently, the country is demanding the national household air pollution policy, national air quality guideline and regular monitoring and measurements protocol of household air pollutants. Therefore, this dissertation result contributed in evidences of the problem and possible recommendations. Providing alternative energy sources, promotion of grid/non-grid electrification, promotion of cleaner cooking fuels and clean cook stoves and supplying other energy sources with government subsidies to reduce biomass burning. Provision of health services and education in preventive measures of health-related problems, standard housing (improved house design) development and promotion for inhabitants are commendable.

11. RECOMMENDATION

To Ministry of Water, Irrigation and Energy:

- ✓ Supplying improved cookstoves, biogas technology, solar power and LPG gas to low income households with government financial subsidy and long-term loan.
- ✓ Promote and support private energy providing sectors

To the local town administration, housing and urban construction office:

- ✓ Promote clean fuel use and improved cook stove
- ✓ Support sectors who are working on low cost energy supply sectors.
- ✓ Support a platform of producing users' friendly and improved cook stoves
- ✓ Introduce better house design (model house) to the community, which contains minimum criteria of better house construction; promote a separate kitchen, to incorporate a sufficient number of windows and rooms in the house in the long run.

To the local town health department:

- ✓ Raise community level awareness via IEC/BCC about the health problems related to biomass smoke, preventive measures of ARI and small sized child, the importance of house ventilation and family planning programs.
- ✓ Aware mothers about the health risks of engaging and carry child in the back while cooking.
- ✓ Design health initiatives (campaign) and promote opening of doors and windows.

To policy makers of Ministry of Health and Environmental protection agency

- ✓ Incorporating household air pollution as one package of health extension program
- ✓ The need to develop and implement emission control programs
- ✓ Incorporating household air pollution in national health policy
- ✓ National air quality standards/guidelines should be developed.

To researchers: for further research directions

- ✓ Further research is required to determine the level of household air pollution from biomass fuels using more direct measures of exposure at personal level.
- ✓ Research on household air pollution considering seasonal variations on fuel use

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13. REFERENCES

1. Gwénaëlle Legros, Ines Havet, Nigel Bruce, Sophie Bonjour. **The Energy Access Situation in Developing Countries: A review focused on least developed countries and sub-Saharan Africa**. Nairobi, Kenya: UNDP and World Health Organization; 2009.

2. WHO. **WHO air quality guidelines global update 2005 Report on aworking group meeting, Bonn, Germany, 18-20 October 2005**. World Health Organization, 2005.

3. Jill Baumgartner, James J. Schauer, Majid Ezzati, Lin Lu, Chun Cheng, Jonathan A. Patz, et al. **Indoor air pollution and blood pressure in adult women living in rural China**. Environ Health Perspect. 2011;119(10):1390-5.

4. Carlos Torres-Duque, Dario Maldonado, Rogelio Perez-Padilla, Majid Ezzati, Giovanni Viegi. **Forum of International Respiratory Societies Report: Biomass Fuels and Respiratory Diseases; A Review of the Evidence**. Proc Am Thorac Soc. 2008;5:577-90.

5. Akunne AF, Louis VR, Sanon M, Sauerborn R. **Biomass solid fuel and acute respiratory infections: The ventilation factor** Int J Hyg Environ Health. 2006;209:445-50.

6. State of Global Air. **State of global air/2018** 2019 [cited 2019 03-Feb-2019]. Available from: https://www.stateofglobalair.org/health.

7. State of Global Air. **Sate of Global Air / 2018, NEW for 2018-Data on exposures to household air pollution** 2019 [cited 2019 03-Feb-2019]. Available from: https://www.stateofglobalair.org/.

8. WHO. **Global Health Observatory data: Mortality from household air pollution** 2019 [cited 2019 03-Feb-2019]. Available from: https://www.who.int/gho/phe/indoor_air_pollution/burden/en/.

9. Chhabi Lal Ranabhat, Chun-Bae Kim, Chang-Soo Kim, Nilambar Jha, K.C Deepak, Fredric A Connel. **Consequence of indoor air pollution in rural area of Nepal: a simplified measurement approach**. Frontiers in public health. 2015;3:5.

10. Nigel Bruce, Rogelio Perez-Padilla, Rachel Albalak. **Indoor air pollution in developing countries: a major environmental and public health challenge**. Geneva, Switzerland: 2000.

11. Bartington SE, Bakolis I, Devakumar D, Kurmi OP, Gulliver J, Chaube G, et al. **Patterns of domestic exposure to carbon monoxide and particulate matter in households using biomass fuel in Janakpur, Nepal**. Environmental Pollution (Barking, Essex : 1987). 2017;220(Pt A):38-45.

12. Smith K.R, Mehta S, M Maeusezahl-Feuz. **Indoor air pollution from household solid fuel use. In: Ezzati M, Lopez AD, Rodgers A, Murray CJL, editors. Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors.** World Health Organization. 2004:1435-93.

13. Kirk R. Smith, Sumi Mehta. **The burden of disease from Indoor air pollution in developing countries: comparison of estimates**. Int J Hyg Environ Health. 2003;206:279-89.

14. Klasen EM, Wills B, Naithani N, Gilman RH, Tielsch JM, Chiang M, et al. **Low correlation between household carbon monoxide and particulate matter concentrations from biomass-related pollution in three resource-poor settings**. Environmental research. 2015;142:424-31.

15. Zhang JF, Morawska L. **Combustion sources of particles: emission factors and measurement methods**. Chemosphere 2002;49:1059-74.

16. Dionisio KL, Stephen R.C.Howie, Francesca Dominici, Kimberly M. Fornace, John D. Spengler, Simon Donkor, et al. **The exposure of infants and children to carbon monoxide from biomass**

fuels in The Gambia: a measurement and modeling study. Journal of Exposure Science and Environmental Epidemiology. 2012;22:173-81.

17. WHO. **WHO Report on "Air pollution and child health: prescribing clean air"** 2019 [cited 2019 07-Feb-2019]. Available from: https://www.medbox.org/air-pollution-and-child-health-prescribing-clean-air/redirect.
18. WWHO. **7 Million premature deaths annually linked to air pollution** 2014 [September 23, 2017]. Available from: http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/.
19. Md Nuruzzaman Khan, Cherri Zhang B Nurs, M. Mofizul Islam, Md Rafiqul Islam, Md Mizanur Rahman. **Household air pollution from cooking and risk of adverse health and birth outcomes in Bangladesh: a nationwide populationbased study**. Environmental Health. 2017;16(57).
20. Jack DW, Asante KP, Wylie BJ, Chillrud SN, Whyatt RM, Ae-Ngibise KA, et al. **Ghana randomized air pollution and health study (GRAPHS): study protocol for a randomized controlled trial**. Trials. 2015;16(1):420.
21. Central Statistical Agency. **Ethiopia Demographic and Health Survey 2011**. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International: 2012.
22. Central Statistical Agency. **Ethiopia Demographic and Health Survey 2016**. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF: 2016.
23. Hayelom Gebrekirstos Mengesha, Alem Desta Wuneh, Berhe Weldearegawi, Divya L Selvakumar. **Low birth weight and macrosomia in Tigray, Northern Ethiopia: who are the mothers at risk?** BMC Pediatrics. 2017;17(144).
24. Mohammad Rifat Haider, Mohammad Masudur Rahman, Farahnaz Islam, M. Mahmud Khan. **Association of Low Birthweight and Indoor Air Pollution: Biomass Fuel Use in Bangladesh**. J Health Pollution. 2016;6(11):18-25.
25. Zeeshan Ahmed, Mubashir Zafar, Naveed Ali Khan, Muhammad Sameer Qureshi. **Exposure to biomass fuel and low child birth weight – Findings of Pakistan Demographic and Health Survey 2006–2007**. International Journal of Health System and Disaster Management. 2015;3(1).
26. Vishnu Khanal, Kay Sauer, Rajendra Karkee, Yun Zhao. **Factors associated with small size at birth in Nepal: further analysis of Nepal Demographic and Health Survey 2011**. BMC Pregnancy and Childbirth. 2014;14(32).
27. Abera Kumie, Emmelin A, Wahlberg S, Berhane Y, Ali A, Mekonnen E, et al. **Magnitude of indoor NO2 from biomass fuels in rural settings of Ethiopia**. Indoor Air. 2009;19(1):14-21.
28. Mestl HE, Aunan K, Seip HM, Wang S, Zhao Y, Zhang D. **Urban and rural exposure to indoor air pollution from domestic biomass and coal burning across China.** Sci Total Environ. 2007b;377:12-26.
29. Tone Smith-Sivertsen, Esperanza Dı´az, Dan Pope, Rolv T. Lie, Anaite Dı´az, John McCracken, et al. **Effect of reducing indoor air pollution on women's respiratory symptoms and lung function: the RESPIRE Randomized Trial, Guatemala**. Am J Epidemiol. 2009;170:211-20.
30. Majid Ezzati, Daniel Kammen. **Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study**. Lancet. 2001;358:619-24.

31. Mukesh Dherani, Daniel Pope, Maya Mascarenhas, Kirk R Smith, Martin Weber, Nigel Bruce. **Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis**. Bull World Health Organ. 2008;86(5):390-8.

32. Smith KR, Uma R, Kishore VVN, Zhang J, Joshi V, MAK Khalil. **Greenhouse implications of household fuels: an analysis for India**. Annual Rev Ener Environ. 2000;25:741-63.

33. Naeher LP, Brauer M, Lipsett M, Zelikoff JT, Simpson CD, Koenig JQ. **Woodsmoke health effects: a review**. Inhal Toxicol. 2007;19(1):67-106.

34. WHO. **Indoor air Pollution and Lower Respiratory Tract Infections in Children: Report of a symposium and a workshop held at the International Society of Environmental Epidemiology, Paris, 4 September 2006, presenting preliminary results of a randomized intervention trial in Guatemala and discussing the implication for policy, advocacy and future research**. Geneva, Switzerland: World Health Organization, 2007.

35. Cynthia Armendáriz Arnez, Edwards Rufus D, Johnson Michael, Zuk Miriam, Rojas Leonora, Jiménez Rodolfo Díaz, et al. **Reduction in personal exposures to particulate matter and carbon monoxide as a result of the installation of a Patsari improved cook stove in Michoacan Mexico**. Indoor air. 2008;18(2):93-105.

36. Wylie B. J, Kishashu Y, Matechi E, Zhou Z, Coull B, Abioye A. I, et al. **Maternal exposure to carbon monoxide and fine particulate matter during pregnancy in an urban Tanzanian cohort**. Indoor Air. 2017;27(1):136-46.

37. Kalpana Balakrishnan, Padmavathi Ramaswamy, Sankar Sambandam, Gurusamy Thangavel, Santu Ghosh, Priscilla Johnson, et al. **Air pollution from household solid fuel combustion in India: an overview of exposure and health related information to inform health research priorities**. Global Health Action. 2011;4(5638).

38. Kalpana Balakrishnan, Jyoti Parikh, Sambandam Sankar, Ramaswamy Padmavathi, Kailasam Srividya, Vidhya Venugopal, et al. **Daily average exposures to respirable particulate matter from combustion of biomass fuels in rural households of southern India**. Environ Health Perspect. 2002;110:1069-75.

39. WHO. **Indoor Air Pollution: National Burden of Disease Estimates. WHO/SDE/PHE/07.01 rev**. Geneva, Switzerland: 2007.

40. Ezzati M, Mbinda BM, DM Kammen. **Comparison of emissions and residential exposure from traditional and improved biofuel stoves in rural Kenya**. Environmental Science and Technology. 2000;34:578-83.

41. Segersson David, Eneroth Kristina, Gidhagen Lars, Johansson Christer, Omstedt Gunnar, Engström Nylén Anders, et al. **Health Impact of PM(10), PM(2.5) and Black Carbon Exposure Due to Different Source Sectors in Stockholm, Gothenburg and Umea, Sweden**. International journal of environmental research and public health. 2017;14(7):742.

42. Majid Ezzati, Daniel M. Kammen. **The Health Impacts of Exposure to Indoor Air Pollution from Solid Fuels in Developing Countries: Knowledge, Gaps, and Data Needs**. Environ Health Perspect. 2002;110:1057-68.

43. Rosana Norman, Brendon Barnes, Angela Mattee, Debbie Bradshaw, The South African comparative risk assessment collaborating group. **Estimating the burden of disease attributable to indoor air pollution from household use of solid fuels in the South Africa in 2000**. S Afr Med J. 2007;97(8):764-71.

44. Mukhopadhyay R, Sambandam S, Pillarisetti A, Jack D, Mukhopadhyay K, Balakrishnan K, et al. **Cooking practices, air quality, and the acceptability of advanced cookstoves in Haryana, India: an exploratory study to inform large-scale interventions**. Glob Health Action. 2012;5:1-13.

45. Kalpana Balakrishnan, Santu Ghosh, Bhaswati Ganguli, Sankar Sambandam, Nigel Bruce, Douglas F Barnes, et al. **State and national household concentrations of PM2.5 from solid cookfuel use: Results from measurements and modeling in India for estimation of the global burden of disease**. Environmental Health Perspectives. 2013;12(77).

46. Edwards RD, Liu Y, He G, Yin Z, Sinton J, Peabody J, et al. **Household CO and PM measured as part of a review of China's National Improved Stove Program**. Indoor Air. 2007;17:189-203.

47. Marzia Simoni, Antonio Scognamiglio, Laura Carrozzi, Sandra Baldacci, Anna Angino, Francesco Pistelli, et al. **Indoor exposures and acute respiratory effects in two general population samples from a rural and an urban area in Italy**. Journal of Exposure Analysis and Environmental Epidemiology. 2004;14:144-52.

48. Ruoting Jiang, Michelle L. Bell. **A Comparison of Particulate Matter from Biomass-Burning Rural and Non-Biomass-Burning Urban Households in Northeastern China**. Environ Health Perspect. 2008;116(7):907-14.

49. Kathie L Dionisio, Stephen RC Howie, Majid Ezzati. **Household concentrations and exposure of children to particulate matter from biomass fuels in The Gambia**. Environ Sci Technol 2012;46(6):3519-27.

50. Habtamu Sanbata, Araya Asfaw, Abera Kumie. **Indoor air pollution in slum neighbourhoods of Addis Ababa, Ethiopia. Indoor Air Pollution (IAP) Updates from the WASHplus Project**. Atmospheric Environment. 2014.

51. Habtamu Sanbata, Araya Asfaw, Abera Kumie. **Association of biomass fuel use with acute respiratory infections among under- five children in a slum urban of Addis Ababa, Ethiopia**. BMC public health. 2014;14:1122.

52. Graham Megan. **Amixed methods of approach to assessing indoor air pollution among women in Addis Ababa**. Atlanta: Emory University; 2011.

53. WHO. **WHO guidelines for indoor air quality: household fuel combustion**. Geneva, Switzerland: WHO, 2014.

54. WHO. **WHO Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide and sulfur dioxide**. Copenhagen: World Health Organization, Regional Office for Europe; 2006, 2006.

55. David Pennise, Simone Brant, Seth Mahu Agbeve, Wilhemina Quaye, Firehiwot Mengesha, Wubshet Tadele, et al. **Indoor air quality impacts of an improved wood stove in Ghana and an ethanol stove in Ethiopia**. Energy for Sustainable Development. 2009;13:71-6.

56. Fullerton DG, Bruce N, S.B Gordon. **Indoor air pollution from biomass fuel smoke is a major health concern in the developing world**. Trans R Soc Trop Med Hyg. 2008;102(9):843-51.

57. Smith KR. **Indoor air pollution in developing countries: recommendations for research**. Indoor air. 2002;12(3):198-207.

58. M Ezzati, H Saleh, D M Kammen. **The Contributions of Emissions and Spatial Microenvironments to Exposure to Indoor Air Pollution from Biomass Combustion in Kenya**. Environ Health Perspect. 2000;108:833- 9.

59. Smith KR, Samet JM, Romieu I, N Bruce. **Indoor air pollution in developing countries and acute lower respiratory infections in children**. Thorax. 2000;55(6):518-32.

60. Clark ML, Reynolds SJ, Burch JB, Conway S, Bachand AM, JL Peel. **Indoor air pollution, cookstove quality, and housing characteristics in two Honduran communities**. Environ Res. 2010 110(1):12-8.

61. Yamamoto S.S, V. R. Louis, A. Sié, R. Sauerborn. **Biomass smoke in Burkina Faso: what is the relationship between particulate matter, carbon monoxide, and kitchen characteristics?** Environ Sci Pollut Res. 2014;21:2581-91.

62. Rahel Albalak, Nigel Bruce, John P. Mccracken, KR Smith, Thelma De Gallardo. **Indoor respirable particulate matter concentrations from an open fire, improved cookstove, and LPG/open fire combination in a rural Guatemalan community**. Environ Sci Technol. 2001;35(13):2650-5.

63. Colbeck, I Nasir, Z. A, Ali Z. **Characteristics of indoor/outdoor particulate pollution in urban and rural residential environment of Pakistan**. Indoor Air. 2010;20:40-51.

64. Kalpana Balakrishnan, Sankar Sambandam, Padmavathi Ramaswamy, Sumi Mehta, KR Smith. **Indoor air pollution associated with household fuel use in India: Exposure assessment for respirable particulates associated with household fuel use in rural districts of Andhra Pradesh, India**. Journal of Exposure Analysis and Environmental Epidemiology. 2004;14:S14-S25.

65. Dasgupta. S, M. Huq, M. Khaliquzzaman, M. Pandey K, D Wheeler. **Indoor air quality for poor families: new evidence from Bangladesh**. Indoor Air. 2006;16:426-44.

66. T.F. O'Brien. **The Importance of Good Ventilation** the Long Island, New York area: T.F. O'Brien Cooling & Heating; 2019 [cited 2019 18-Feb-2019].

67. Kebede Faris. **Survey of Household air pollution problems in the rural communities of Jimma, Southwest Ethiopia**. Ethiopian Journal of Health Sciences. 2002;12:1-13.

68. Van Vliet ED, Asante K, Jack DW, Kinney PL, Whyatt RM, Chillrud SN, et al. **Personal exposures to fine particulate matter and black carbon in households cooking with biomass fuels in rural Ghana**. Environ Res. 2013;127:40-8.

69. Edelstein M, Pitchforth E, Asres G, Silverman M, Kulkarni N. **Awareness of health effects of cooking smoke among women in the Gondar Region of Ethiopia: a pilot survey**. BMC International Health and Human Rights. 2008;8(10).

70. Ramesh Bhat Y, N. Manjunath, D. Sanjay, Y. Dhanya. **Association of household air pollution with acute lower respiratory tract infections in children under 5 years of age**. Paediatrics and International Child Health 2012;32(3).

71. Stewart Jackson, Kyle H. Mathews, Dražen Pulanić, Rachel Falconer, Igor Rudan, Harry Campbell, et al. **Risk factors for severe acute lower respiratory infections in children - a systematic review and meta-analysis**. Improving global child health. 2013;54:110-21.

72. Pope D, Mishra V, Thompson L, Siddiqui AR, Rehfuess EA, M Weber. **Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries**. Epidemiol Rev. 2010;32:70-81.

73. Kurmi O.P, Semple S, Simkhada P, Smith WCS, Ayres J.G. **COPD and chronic bronchitis risk of indoor air pollution from solid fuel: a systematic review and meta-analysis**. Thorax. 2010;65:221-8.

74. Sapkota A, Gajalakshmi V, Jetly DH, Roychowdhury S, Dikshit RP, P Brennan. **Indoor air pollution from solid fuels and risk of hypopharyngeal/laryngeal and lung cancers: a multi centric case-control study from India**. Int J Epidemiol. 2008;37:321-8.

75. Brunekreef B, Forsberg B. **Epidemiological evidence of effects of coarse airborne particles on health**. Eur Respir J. 2005;26(2):309-18.

76. Janjua N.Z, Mahmood B, Dharma V.K, Sathiakumar N, MI Khan. **Use of biomass fuel and acute respiratory infections in rural Pakistan**. Public health. 2012;126(10):855-62.

77. Eldred Tunde Taylor, Satoshi Nakai. **Prevalence of acute respiratory infections in women and children in Western Sierra Leone due to smoke from wood and charcoal stoves**. International journal of environmental research and public health. 2012;9(6):2252-65.

78. Ezzati M, D.M Kammen. **Quantifying the effects of exposure to indoor air pollution from biomass combustion on acute respiratory infections in developing countries**. Environmental Health Perspectives. 2001;109(5):481-8.

79. Health Effects Institute. **Review Panel on Ultrafine Particles. Understanding the Health Effects of Ambient Ultrafine Particles. HEI Perspectives 3. Health Effects Institute**. Boston 2013.

80. Mekuriaw Alemayehu, Kassahun Alemu, Hardeep R. Sharma, Zemicheal Gizaw. **Household Fuel Use and Acute Respiratory Infections in Children Under Five Years of Age in Gondar city of Ethiopia**. Journal of Environment and Earth Science. 2014;4(7).

81. Mekonnen Maschal Tarekegn, Tigist Yohannes Gulilat. **Trends of Ambient Air Pollution and the Corresponding Respiratory Diseases in Addis Ababa**. Clinical Pharmacology & Toxicology Journal. 2018;2(1:5).

82. Harrison's. **Principles of internal medicine**. United states of America: The McGraw-Hill Companies, Inc.; 2012.

83. Clark ML, Peel JL, Balakrishnan K, Breysse PN, Chillrud SN, Naeher LP, et al. **Health and household air pollution from solid fuel use: the need for improved exposure assessment**. Environ Health Perspect. 2013;121(10):1120-8.

84. Simone Simões Amaral, João Andrade de Carvalho Jr., Maria Angélica Martins Costa, Cleverson Pinheiro. **An Overview of Particulate Matter Measurement Instruments**. Atmosphere. 2015;6(9):1327-45.

85. RION. **Particle counters General Catalogue** Japan2019 [cited 2019 18-Feb-2019]. Available from: https://www.rion.co.jp/english/product/particle/pdf/particle-E.pdf.

86. Amanda Northcross, Zohir Chowdhury, John McCracken, Eduardo Canuz, Kirk R. Smith. **Estimating personal PM2.5 exposures using CO measurements in Guatemalan households cooking with wood fuel**. Journal of Environmental Monitoring. 2010;12:873-8.

87. Kasim OF, Abshare MW, Agbola SB. **Analysis of air quality in Dire Dawa, Ethiopia**. Journal of the Air & Waste Management Association. 2018;68(8):801-11.

88. Tadele Tafese, Belaynesh Tamre. **Household energy choice and demand in urban Ethiopia: case of Wolaita zone**. International journal of research in commerce, economics & management. 2015;5(11):5-10.

89. Wolaita Sodo Municipality. **Wolaita Sodo Town Municipality: Annual performance report of the year 2015**. Wolaita Sodo: Sodo town Municipality; 2015.

90. R. Bonita, R. Beaglehole, Kjellström. T. Basic epidemiology. 2nd ed. 20 Avenue Appia, 1211 Geneva 27, Switzerland: World Health Organization; 2006. 212 p.

91. WHO. **Acute Respiratory Infections in Children: Case Management in Small Hospitals in Developing Countries: A Manual for Doctors and Other Senior Health Workers**. Geneva, Switzerland: 1990.

92. Vinod Mishra. **Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe**. Int J Epidemiol. 2003;32:847-53.

93. Sikolia DN, K2) M, Kurui J, Cherop H, Bwika A, Seki I, et al. **The Prevalence of acute respiratory infections and the associated risk factors: A Study of children under five years of age in Kibera Lindi Village, Nairobi, Kenya**. J Natl Inst Public Health. 2002;51(1):67-72.

94. Kelsey JL, Whittemore AS, Evans AS, Thompson WD. Methods in Observational Epidemiology. New York: Oxford University Press; 1996.

95. Joseph L. Fleiss, Bruce Levin, Myunghee Cho Paik. Statistical Methods for Rates and Proportions. 3 ed: John Wiley & Sons; 2003.

96. Smith KR. **Development of the UCB-L Particle Monitor: For Future California Applications in Environmental Justice; School of Public Health University of California Berkeley, Prepared for the California Air Resources Board and the California Environmental Protection Agency**. 2010.

97. University of California Berkeley. **Standard Operating Procedure Installing Indoor Air Pollution Instruments in a Home**. University of California Berkeley: Indoor Air Pollution Team and Center for Entrepreneurship in International Health and Development (CEIHD) School of public health, University of California Berkeley; 2005.

98. Amar M. Taksande, Mayuri Yeole. **Risk factors of Acute Respiratory Infection (ARI) in under-fives in a rural hospital of Central India**. Journal of Pediatric and Neonatal Individualized Medicine. 2016;5(1).

99. Sharma D, Kuppusamy K, Bhoorasamy A. **Prevalence of acute respiratory infections (ari) and their determinants in under five children in urban and rural areas of Kancheepuram district, South India**. Annals of Tropical Medicine and Public Health. 2013;6(5):513-8.

100. Walke SP, Das R, Acharya AS, Pemde HK. **Incidence, Pattern, and Severity of Acute Respiratory Infections among Infants and Toddlers of a Peri-Urban Area of Delhi: A 12-Month Prospective Study**. International Scholarly Research Notices. 2014;2014:6.

101. Dherani M, Pope D, Mascarenhas M, Smith KR, Weber M, N Bruce, et al. **Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis**. Bull World Health Organ. 2008;86(5):390-8.

102. Apte K, Salvi S. **Household air pollution and its effects on health**. F1000Research. 2016;5:F1000 Faculty Rev-2593.

103. Das I, Pedit J, Handa S, Jagger P. **Household air pollution (HAP), microenvironment and child health: Strategies for mitigating HAP exposure in urban Rwanda**. Environmental research letters : ERL [Web site]. 2018;13(4):045011.

104. FA Ujunwa, CT Ezeonu. **Risk Factors for Acute Respiratory Tract Infections in Under-five Children in Enugu Southeast Nigeria**. Ann Med Health Sci Res. 2014;4(1):95-9.

105. Helen GS, Aguilar-Villalobos M, Adetona O, Cassidy B, Bayer CW, Hendry R, et al. **Exposure of Pregnant Women to Cookstove-Related Household Air Pollution in Urban and Periurban Trujillo, Peru**. Archives of Environmental & Occupational Health. 2015;70(1):10-8.

106. Vinod Joon, Harshika Kumari, Avinash Chandra. **Predicting Exposure Levels of Respirable Particulate Matter (PM2.5) and Carbon monoxide for the Cook from Combustion of Cooking fuels**. In: IPCBEE, editor. International Conference on Chemistry and Chemical Process; Singapore: IACSIT Press; 2011.

107. Michael Johnson, Nick Lam, Simone Brant, Christen Gray, David Pennise. **Modeling indoor air pollution from cookstove emissions in developing countries using a Monte Carlo single-box model**. Atmospheric Environment. 2011;45:3237-43.

108. WHO. **WHO guidelines for indoor air quality: selected pollutants**. Bonn: World Health Organization: WHO, 2010.

109. Gaia Association. **Indoor Air Pollution Monitoring Summary For Gaia Association-Ethiopia's Clean Cook Stove Tests in Addis Ababa, Ethiopia**. 2007.

110. Chris Keil, Hailu Kassa, Alexander Brown, Abera Kumie, Worku Tefera. **Inhalation Exposures to ParticulateMatter and Carbon Monoxide during Ethiopian Coffee Ceremonies in Addis Ababa: A Pilot Study**. Journal of Environmental and Public Health. 2010;2010:8.

111. Chen C, Zeger S, Breysse P, Katz J, Checkley W, Curriero FC, et al. **Estimating Indoor PM(2.5) and CO Concentrations in Households in Southern Nepal: The Nepal Cookstove Intervention Trials**. PLoS ONE. 2016;11(7):e0157984.

ANNEX-I: ORIGIBNAL PAPERS

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Research Article

Children under Five from Houses of Unclean Fuel Sources and Poorly Ventilated Houses Have Higher Odds of Suffering from Acute Respiratory Infection in Wolaita-Sodo, Southern Ethiopia: A Case-Control Study

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Background. Acute respiratory tract infection is the most common illness in childhood. Ninety-five percent (99% of rural and 80% of urban) of households in Ethiopia primarily use solid fuel for cooking. This study investigated the effect of household fuel use and house ventilation on acute respiratory infection in children, Wolaita-Sodo, Southern Ethiopia. *Methods.* A community based case-control study design was used, covering a sample of 1144 children with ratio of 1 : 3 (286 cases and 858 controls) aged between 0 and 59 months. A case was defined as a child who suffered from cough, followed by short, rapid breathing in the last two weeks that preceded the survey, while control was defined as a child who had not any of the respiratory infection signs and symptoms. Study subjects were recruited after a census from households. Data were entered using EpiData version 3.1 and analyzed using SPSS version 21. *Results.* The proportion of children aged 1–3 years and 3–5 years was 76% and 24%, respectively. Two-thirds of children lived in households that used solid fuels for cooking (charcoal 62.76% and biomass 24.73%). The majority of households (83%) used open/traditional three-stone stoves. Unclean fuel users for cooking (AOR = 2.09, 95% CI 1.03–4.22), poorly ventilated houses (AOR = 4.32, 95% CI 2.61–7.15), large family size (AOR = 1.85, 95% CI 1.31–2.62), and carrying of a child while cooking (AOR = 1.66, 95% CI 1.18–2.34) were significant risk factors of acute respiratory infection in children under five. *Conclusions.* Children from houses of unclean fuel sources and poorly ventilated houses were more likely to be affected by acute respiratory infection. Using clean energy sources and improved stoves is highly suggested.

1. Background

The entire world used solid fuels (biomass and coal) for cooking more than a century; now more than 60% use gas and/or electricity-fuels that are basically clean at use [1]. Households burn such solid fuels in inefficient devices and in poorly ventilated kitchens. These result in very high exposures to multiple toxic products of incomplete combustion [2–4]. People in developing countries are commonly exposed to very high levels of pollution for 3–7 hours daily over many years [5]. Most of daily exposures to household air pollution (HAP) are because of the greater amount of time spent in household and the higher pollution levels of households [6]. HAP varies depending on the type of fuel, stove, housing characteristics, fuel moisture content, the practice of the people using the stoves, and the stove technology [7]. Unclean fuels are often burned in inefficient, poorly vented combustion devices. The incomplete combustion of these solid fuels results in much of the fuel energy being emitted as potentially toxic pollutants [8]. Biomass fuel combustion results in severe household air pollution and has been associated with increased risk for acute lower respiratory tract infections [9]. The incidence of ARI was higher in children who live in houses where biomass fuel was used and who accompanied their mothers while cooking compared with children living in houses [10]. The odds of having suffered from ARI were large with woodstoves homes relative to charcoal stoves [11]. An exposure to indoor air pollution was risk factor for severe lower acute respiratory infections in children [12].

A study in Ghana indicated that 99% of the households used biomass as their primary fuel, 55% cooked outdoors, and 77% cooked on traditional fires [13]. According to 2016 Ethiopian Demographic and Health Survey (EDHS) report, 93% (70.6% of urban and 98.8% of rural) of households use solid fuel as a primarily source of energy for cooking [14]. A study in Gondar and Addis Ababa revealed that 54.7% and 60% of the children lived in households using biomass fuels, respectively; furthermore biomass fuel users were more likely to have ARI in children than clean fuel users in both studies [15, 16].

Culturally, in Ethiopia women are expected to cook foods, care for children, and serve their families. Women carry their child on their back while cooking and children spent hours close to cooking fire with their mother and consequently have high exposures to health-damaging pollutants. The housing design and structures of houses in Ethiopia are not suitable in ways that can exhaust household air pollutants; as a result, incomplete combustion of fuels and poor ventilation result in high household concentrations of health-damaging pollutants and women and young children are exposed to high level of household air pollution every day. Hence, the aim of this study was to investigate the effects of household fuel use and house ventilation on acute respiratory infection in children in Wolaita-Sodo, Southern Ethiopia.

2. Methods

2.1. Study Context. The study was conducted in Wolaita-Sodo town in February 2017. Wolaita-Sodo town is located 329 kilometers away from Addis Ababa. The town has three subcities and 11 districts with a population of 111,616 and 22,777 households. The number of women whose age is between 15 and 49 years was 3829; and the number of children under five was 17,421. The town has one private and one government hospital. There are health centers, private clinics, and drug vendors. Sources of fuels used for cooking in the households of Wolaita-Sodo town are firewood 94.6%, charcoal 96.6%, kerosene 11.5%, electricity 14.2%, crop residue 2.02%, dung cake 6%, and saw dust 23.7% [17].

2.2. Study Design. A community based unmatched case-control study design was used to ascertain the relationship between unclean fuel source used for cooking and acute respiratory infection in children aged between 0 and 59 months.

2.3. Study Population. All children under five in the selected districts were source population. The study population was the selected children under five whose age was between 0 and 59 months paired with their mother or care giver, who were living in Wolaita-Sodo town. Eligibility criteria were availability of a child to be screened for ARI, residents of Wolaita-Sodo town (living at least six months in Wolaita-Sodo town), and one child per household only. The study excluded a mother or care giver of a child who was seriously ill during data collection or a child who was on treatment for confirmed tuberculosis.

2.4. Selection of Cases and Controls. The presence of ARI cases in children was assessed by interviewing of their mothers or care givers using WHO criteria of ARI case definition. This is in agreement with existing literatures [18, 19]. During the census, those children who fulfilled the WHO criteria of ARI were reconfirmed by the supervisors using the same criteria. Control was defined, if a child had not any acute respiratory infection sign and symptoms.

2.5. Sample Size and Sampling Procedure. The sample size calculation was determined based on two-population proportion formula accounting for unmatched case-control study design. The design considered a confidence level of 95% and power of 80% and ratio of case-to-control number was 1 : 3, and the least extreme odds ratio to be detected was 2.00. A proportion of controls with biomass fuel exposure (17.4%) were taken from a study conducted in rural area of Nepal [5]. Based on the above assumptions, the sample size was calculated by the Open Epi Version 3.03 (Open source Epidemiologic Statistics for Public Health). Having considered a design effect of 2 and a 10% of nonrespondent rate, the final sample size was 1148 (i.e., 287 cases and 861 controls).

The town has three subcities, with a total of 11 districts. Six districts were selected randomly. The selected districts were clusters with assumption of homogenous characteristics. Census was conducted in the selected districts in order to enumerate the number of children, as cases and controls, code households, and setting sampling frame. Based on the census data, all sample sizes (1148 households) were allocated based on Probability Proportional to Size (PPS) of the population in each selected district. Then, each household was selected using Systematic Random Sampling (SRS) technique, at the interval of every other case child. When the case child had been once selected, then the next three consecutive control's households were interviewed. If there were two children under five in the same house, one child was selected randomly using lottery method.

2.6. Data Collection Procedures and Tools. Interviewer administered face-to-face interview was conducted using a close-ended structured questionnaire that contains sociodemographic variables, the exposure related questions, fuel use, stove type, housing characteristics, type of kitchen, cooking practice, smoking history (smoking status, pack-years of smoking, and second-hand smoke), occupational history, and medical history. The questionnaire was adopted from WHO and Demographic and Health Survey (DHS) questions to meet the context of the study area [20].

Data collectors were public health officers who were trained for three days on the content of the questionnaire, how to screen and refer sick children to a clinic. Each data collector did 5–7 households pretesting of the questionnaire. Based on the pretest input, the questionnaire was restructured and remodified. Two supervisors (M.S. in Public Health) were employed who took similar training to data collectors and their role was to supervise the completeness, accuracy, and consistency of data and reconfirm cases.

2.7. Operational Definition

Acute Respiratory Infection (ARI). This includes a child who suffered from cough, followed by short, rapid breathing in the last two weeks that preceded the survey [21].

Improved Water Source. This includes a piped source within the dwelling, yard, or plot; a public tap/stand pipe, or borehole; a protected well; spring water and rainwater [14].

Level of House Ventilation. This includes the following: good (a house with more than one door and one window), moderate (a house with one door and one window), and poor (a house with only one door and no window).

2.8. Data Management and Analysis. The collected data were reviewed and checked for completeness by the supervisors and principal investigators. Completed questionnaire was coded and entered into computer software program, EpiData version 3.1. Data cleaning and analysis were done using SPSS version 21. Significantly associated variables in unconditional bivariate logistic analysis were entered into a multivariable analysis using Enter Method of Regression. Each variable was tested for collinearity (at Variance Inflation Factor < 10 and Tolerance Test > 0.1) prior to multivariate analysis. Hosmer-Lemeshow goodness-of-fit test was used in multivariable analysis to check the adequacy of the model. In both analyses, the cut-off point for P value was <0.05. Finally, data were presented in tables and narration.

2.9. Data Quality Assurance. During the census and data collection time, houses were labeled with a code number and the code was recorded on the questionnaire. Regular supervision and follow-up were made by supervisors and the principal investigator. To ensure the quality of data, high emphasis was given in designing data collection instrument. Prior to the data collection pretest was made on 60 households which accounted for 5% of the total sample size in nonselected districts. ARI cases were screened by data collectors using WHO case definition. Cases were verified by supervisors by asking similar questions to the mothers and care takers.

2.10. Ethical Consideration. Ethical clearance to undertake the study was obtained from Addis Ababa University, College of Health Sciences, Institutional Review Board Office. Informed consent to participate in the study was obtained before conducting the interview. For this, one-page subject information sheet and informed consent letter were attached to each questionnaire. Participation was in voluntary manner and private information was confidential. Participants were informed that participating in this research has no any risk or harm to the child as well as to the whole family too. The right of the respondent to withdraw from the interview or not to participate was respected. All children who suffered from ARI in the course of the screening period were referred to the nearby health facility for appropriate medical attention.

3. Results

3.1. Sociodemographic Characteristics. A total of 1144 children (286 cases and 858 controls) were included in the study with response rate of 99.6%. The mean age of the mother was 26.89 ± 6.0 years. Two hundred ten (18.36%) of mothers were employed, while 544 (47.55%) were housewives. Eight hundred thirty-one (72.6%) of the households had a family of 5 or less (Table 1).

3.2. Maternal and Child Related Variables. Children were relatively equally distributed by age. The mean age of the children was 24.15 ± 14.98 months. The largest age group of 330 (28.86%) were between 12 and 23 months. Males accounted for 606 (52.97%) of the total children. Almost half of the children, 642 (56.1%) of children, had a birth interval less than or equal to two years. Seven hundred forty-five (65.12%) of children shared their bed room with two people (Table 2).

3.3. Kitchen and House Characteristics. About 712 (62.23%) of households had a kitchen separated from the main house, while 351 (30.68%) of households had kitchen inside the living house. Only, 417 (58.5%) of the kitchen had no chimney; 666 (93.54%) did not open windows during the cooking time. About 508 (44.4%) of children lived in the house of one window (Table 3).

3.4. Type of Fuel, Stove, and Home Practice. Almost two-thirds of children live in households that used polluting fuel for cooking, charcoal 718 (62.76%), followed by biomass fuel 283 (24.73%); that is, only 143 (12.5%) of the households used clean fuel energy, such as electricity, biogas, and Liquefied Petroleum Gas (LPG). The majority, 950 (83.04%), of the households used open/traditional three-stone stoves. Five hundred fifty-two (44.75%) of the respondents spent at least 2 hours per day in cooking foods. Only one-third of the children were present around the cooking stove while mothers were cooking meal. Almost less than one-third of children had a habit of being carried by their mothers or care giver while cooking meal (Table 4).

3.5. Bivariate and Multivariate Analysis. Predictor variables of acute respiratory infection in children under five were analyzed using binary logistic regression, and hence significantly associated variables in bivariate analysis were entered to the multivariable logistic regression model. Unclean fuels (biomass fuel and charcoal) used for cooking showed a significant effect on children ARI as compared to unclean fuels (electricity, LPG, and biogas) (OR: 2.09; 95% CI 1.03–4.22). The odds of ARI were four times higher in children who were living in poorly ventilated houses (only one room, one door, and no window) than living in houses having good ventilation (more than two rooms, doors, and windows) (OR: 4.32; 95% CI 2.61–7.15). The odds of ARI in children were nearly twice higher in households with family members of more than five than they were in family members of five or less (OR 1.85; 95% CI 1.31–2.62). Children being carried on the back of their mother showed a more significant association than those who had never been carried (OR 1.66; 95% CI 1.18–2.34) (Table 5).

TABLE 1: Relationship between sociodemographic characteristics of households in ARI, Wolaita-Sodo, Ethiopia, February 2017 (n = 1144).

Sociodemographic characteristics	Case, n (%)	Control, n (%)	Total, n (%)
Mother age			
15–24 years	94 (27.2)	252 (72.8)	346 (30.24)
25–44 years	189 (24.2)	592 (75.8)	781 (68.26)
45+ years	3 (17.6)	14 (82.4)	17 (1.48)
Educational status of the mother			
No education	98 (8.6)	233 (20.4)	331 (28.9)
Primary level	109 (33.4)	217 (66.6)	326 (28.50)
Secondary level	46 (18.7)	200 (81.3)	246 (21.5)
Higher level	33 (13.7)	208 (86.3)	241 (21.07)
Employment			
Employed	30 (14.3)	180 (85.7)	210 (18.36)
Petty trade	37 (18)	168 (82)	205 (17.92)
Unemployed	61 (5.3)	124 (10.8)	185 (16.2)
Housewife	158 (29)	386 (71)	544 (47.55)
Family size			
≤5 families	190 (22.9)	641 (77.1)	831 (72.6)
>5 families	96 (30.7)	217 (69.3)	313 (27.4)
Main drinking water source			
Improved	264 (23.1)	817 (71.4)	1081 (94.5)
Nonimproved	264 (23.1)	41 (3.6)	63 (5.5)
The type of latrine			
No latrine	10 (20)	40 (80)	50 (4.37)
Pit latrine	246 (25.3)	726 (74.7)	972 (84.96)
VIPL	21 (22.1)	74 (77.9)	95 (8.3)
Water pouring	9 (33.3)	18 (66.7)	27 (2.36)

4. Discussion

Biomass and charcoal fuel are chief sources of fuel by almost all participant households' in this study. From the results, the main type of cooking fuel in the household was analyzed against children ARI. Unclean fuel users showed a significant effect on children ARI as compared to clean fuel users for cooking. This study result was in line with previous studies. Biomass cooking fuel was significantly associated with acute lower respiratory tract infection in India (OR 4.73, 95% CI 1.67–13.45) [9]; the incidence of ARI was higher in children living in houses where biomass fuel was used for cooking (RR 1.5, 95% CI 1.2–1.9) [10] and in a study of systematic review and meta-analysis, the overall pooled odds ratio of unprocessed fuel use and risk of pneumonia was (OR 1.78, 95% CI 1.45–2.18) [22]. Generally, children from biomass fuel user households were more likely to suffer from ARI than clean fuel users. The reason could be that biomass fuel and charcoal emit small sized particulate matter which is able to deposit in the lungs. Deposited particulate matters may alter airway reactivity to antigens or affect the ability of the lungs to handle bacteria, suggesting that exposure may result in enhanced susceptibility to microbial infection [4]. This implies that if children were exposed to biomass and charcoal fuel, they would have higher chance of getting ARI.

The number of doors and windows is pertinent in improving house ventilation and also associated with children ARI. The odds of ARI in children who are living in poorly ventilated houses were four times higher than living in houses that had good ventilation. This study was consistent with the study conducted in slum areas of Addis Ababa, with odds ratio of 2.96 (95% CI: 1.38–3.87) in the study houses [16]. This indicated that smokes from poorly ventilated houses could lead to higher chance of exposing the child.

A habit of carrying children on the back of mothers was linked to children ARI; the odds of ARI were twice higher in children who had been carried on the back while cooking than those who had never been carried. This was similar to the study done in Gondar, 2.68 (95% CI: 1.12–6.48) [15], in Addis Ababa, 1.78 (95% CI: 1.09–2.87) [16]. Both studies revealed that a child who had been carried on the back of mothers while cooking had more risk of developing ARI. Carrying child on the back of mothers while cooking is a deep rooted culture in Ethiopia, where women are responsible for taking care of their children and preparing meal to the family. In this study, women spent much time in cooking to serve the family, with the mean and standard deviation of 2.24 ± 1.06 hours, which was consistent with the study of Taylor and Nakai, where women spent 1–3 hours in the kitchen [11], and the study of Clark et al. depicted that women

Table 2: Relationship between maternal and child related variables in ARI, Wolaita-Sodo, Southern Ethiopia, February 2017 ($n = 1144$).

Characteristics	Case, n (%)	Control, n (%)	Total, n (%)
Sex of the child			
Male	145 (23.9)	461 (76.1)	606 (53)
Female	141 (26.2)	397 (73.8)	538 (47)
Child age			
0–11 months	62 (22.1)	219 (77.9)	281 (24.6)
12–23 months	99 (30)	231 (70)	330 (28.8)
24–35 months	57 (22)	202 (78)	259 (22.6)
36–47 months	43 (25)	129 (75)	172 (15)
48–59 months	25 (24.5)	77 (75.5)	102 (8.9)
ANC follow-up			
Yes	274 (24.8)	832 (75.2)	1106 (96.68)
No	12 (31.6)	26 (68.4)	38 (3.32)
Birth interval			
>=2 years	177 (72.4)	465 (27.6)	642 (56.1)
>2 years	109 (21.7)	393 (78.3)	502 (43.9)
Child schooling			
Yes	60 (29.6)	143 (70.4)	203 (17.74)
No	226 (24)	715 (76)	941 (82.25)
Bedroom shared with the child			
1 person	48 (23.4)	157 (76.6)	205 (17.91)
2 persons	186 (25)	559 (75)	745 (65.12)
>=3 persons	52 (26.8)	142 (73.2)	194 (16.95)
Breastfeeding started time			
Within 1 hour	214 (24.8)	650 (75.2)	864 (87.71)
Within 24 hours	25 (24.8)	76 (75.2)	101 (10.25)
>24 hours	7 (35)	13 (65)	20 (2)

spent a long time in cooking activities with a mean and standard deviation of 6.5 ± 4.3 hours in a day [23]. Both studies revealed that ARI prevalence appears to increase with increase in time spent in kitchens. This implies that if children stayed on the back of their mother for longer period, child would have equal level of smoke exposure as their mothers do.

In terms of the household's family size, the odds of ARI in children were twice higher in households with a family member of more than five than they were in a family member of five or less. The result of this study was in agreement with the study done in central India, where 53.2% of cases with history of overcrowding in family had a high risk of ARI compared to the control group, 22.8% ($P < 0.0001$, OR = 3.84) [24]; in Nigeria, a family size of more than 5 siblings living in a home was shown to affect significantly the prevalence of pneumonia [25], and a systematic study with meta-analysis revealed that crowding of a house (more than 7 persons in a household or more than 2 persons per room) is a risk factor for severe acute lower respiratory infection [12]. The implication of large family sizes was that the crowding of a house affects the health of inhabitants with high chance of transmission of droplets of infective organisms between them.

5. Limitations of the Study

The study lacked individual exposure measurements of specific pollutants like particulate matter, carbon monoxide, and others. This research also might have suffered a recall bias as case-control studies are inherent with this type of bias. The research team tried to operationalize variables, used appropriate and professional data collectors and supervisors, and used standard method of classifications of cases and controls.

6. Conclusion

Unclean fuel source, primarily biomass fuel and charcoal, had an effect on acquiring of ARI. Carrying child on the back during cooking time and child living with a family of more than five were determinant factors for the development of child ARI. Therefore, the most feasible recommendation is to distribute locally accessible and affordable clean energy supply to the community, particularly improved cook stoves. The community should therefore be given health education on the preventive measures of ARI, the role of biomass fuel combustion, house ventilation, and family planning programs. Mothers should be informed about the threats of engaging

Table 3: Relationship between kitchen and house characteristics in ARI, Wolaita-Sodo, Ethiopia, February 2017 ($n = 1144$).

Kitchen and house characteristics	Case, n (%)	Control, n (%)	Total, n (%)
Kitchen arrangement			
Inside the house	125 (35.6)	226 (64.4)	351 (30.68)
Separate building	136 (19.1)	576 (80.9)	712 (62.23)
Outdoor/open	25 (30.9)	56 (69.1)	81 (7.08)
Separate kitchen			
Yes	136 (19.1)	576 (80.9)	712 (62.2)
No	150 (34.7)	282 (65.3)	432 (37.8)
Kitchen has a chimney			
Yes	48 (16.3)	247 (83.7)	295 (41.43)
No	88 (22.1)	329 (78.9)	417 (58.56)
Floor material of kitchen			
Soil/mud	127 (19.2)	533 (80.8)	660 (92.7)
Cement	9 (17.3)	43 (82.7)	52 (7.3)
Windows open during cooking?			
Yes	12 (26.1)	34 (73.9)	46 (6.46)
No	124 (18.4)	542 (81.4)	666 (93.54)
# of rooms			
1 room	118 (34)	229 (66)	347 (30.33)
2 rooms	106 (34)	366 (77.5)	472 (41.25)
3+ rooms	62 (19.1)	263 (80.9)	325 (28.4)
# of windows			
No window	22 (34.4)	42 (65.6)	64 (5.59)
1 window	159 (31.3)	349 (68.7)	508 (44.4)
2 windows	67 (17.1)	325 (82.9)	392 (34.26)
3+ windows	38 (21.1)	142 (78.9)	180 (15.73)

Table 4: Relationship between fuel types, stoves, and home practices in ARI, Wolaita-Sodo, Ethiopia, February 2017 ($n = 1144$).

Characteristics of fuel and stove types	Case, n (%)	Control, n (%)	Total, n (%)
Type of fuel mainly used for cooking			
Biomass fuel	143 (50.5)	140 (49.5)	283 (24.73)
Charcoal	122 (17)	596 (83)	718 (62.76)
Electricity	21 (14.7)	122 (85.3)	143 (12.5)
Type of fuel mainly used for cooking			
Clean fuel	21 (14.7)	122 (85.3)	143 (12.5)
Nonclean fuel	265 (26.5)	736 (73.5)	1001 (87.5)
Type of cooking stove usually used			
Open stove	258 (27.2)	692 (72.8)	950 (83.04)
Improved stove	11 (10.9)	90 (89.1)	101 (8.82)
Electric stove	17 (18.3)	76 (81.7)	93 (8.12)
Time spent in cooking			
1 hour	66 (24.4)	205 (75.6)	271 (23.7)
2 hours	120 (23.4)	392 (76.6)	512 (44.8)
3+ hours	100 (27.7)	261 (72.3)	361 (31.6)
Child usually present during cooking			
Yes	123 (32.1)	260 (67.9)	383 (33.47)
No	163 (21.4)	598 (78.6)	761 (66.52)
Habit of carrying a child while cooking			
Yes	106 (34.4)	202 (65.6)	308 (26.9)
No	180 (21.5)	656 (78.5)	836 (73.07)
Family member smokes cigarette			
Yes	11 (50)	11 (50)	22 (1.92)
No	275 (24.5)	847 (75.5)	1122 (98.0)

Table 5: Logistic regression model for ARI, Wolaita-Sodo, Southern Ethiopia, February 2017.

Predictor variables	Case	Control	AOR (95% CI)	COR (95% CI)
Educational status of the mother				
Illiterate	98	233	1.40 (1.05–1.86)*	0.94 (0.67–1.31)
Literate	188	625	1.00	1.00
Employment status				
Employed	30	180	1.00	1.00
Petty trade	37	168	1.32 (0.78–2.24)	1.10 (0.62–1.96)
Unemployed	61	124	2.95 (1.80–4.83)*	2.21 (1.27–3.85)*
Housewife	158	386	2.46 (1.60–3.77)*	1.97 (1.23–3.15)*
Family size				
≤5 families	190	641	1.00	1.00
>5 families	96	217	1.49 (1.12–1.99)*	1.85 (1.31–2.62)*
Birth interval				
<=2 years	177	465	1.37 (1.04–1.80)*	1.41 (1.03–1.92)*
>2 years	109	393	1.00	1.00
Number of rooms in the house				
1 room	118	229	2.18 (1.53–3.11)*	1.46 (0.81–2.66)
2 rooms	106	366	1.22 (0.86–1.74)	1.15 (0.70–1.90)
3+ rooms	62	263	1.00	1.00
Number of windows of the house				
No window	22	42	1.95 (1.04–3.66)*	0.77 (0.32–1.84)
1 window	159	349	1.70 (1.13–2.55)*	0.71 (0.37–1.38)
2 windows	67	325	0.77 (0.49–1.20)	0.51 (0.29–1.92)
3+ windows	38	142	1.00	1.00
Level of house ventilation				
Poor	186	288	4.62 (2.92–7.30)*	4.32 (2.61–7.15)*
Moderate	75	391	1.37 (0.84–2.23)	1.58 (0.93–2.68)
Good	25	179	1.00	1.00
Kitchen arrangement				
Inside the house	125	226	1.23 (0.73–2.08)	1.54 (0.85–2.76)
Separate building	136	576	0.52 (0.31–0.87)*	0.70 (0.39–1.26)
Outdoor/open	25	56	1.00	1.00
Type of fuel mainly used for cooking				
Clean fuel	21	122	1.00	1.00
Nonclean fuel	265	736	2.09 (1.29–3.39)*	2.09 (1.03–4.22)*
Type of stoves usually used				
Open stove	258	692	1.00	1.00
Improved stove	11	90	0.32 (0.17–0.62)*	0.62 (0.30–1.24)
Electric stove	17	76	0.60 (0.34–1.03)	1.91 (0.87–4.20)
Child usually present during cooking				
Yes	123	260	1.73 (1.31–2.28)*	1.28 (0.92–1.78)
No	163	598	1.00	1.00
Habit of carrying a child while cooking				
Yes	106	202	1.91 (1.44–2.55)*	1.66 (1.18–2.34)*
No	180	656	1.00	1.00
Family member smoke cigarette				
Yes	11	11	3.08 (1.32–7.18)*	1.84 (0.69–4.90)
No	275	847	1.00	1.00

* indicates those that are significant at P value < 0.05; 1.00 indicates the reference category.

and carry children on the back during cooking time. Further research is required to determine the level of HAP from biomass fuels using more direct measures of exposure.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors were involved in study protocol design and development. Amha Admasie was involved in data collection. Amha Admasie and Alemayehu Worku were involved in data analysis. Amha Admasie prepared the manuscript and it was edited by Abera Kumie. Abera Kumie and Alemayehu Worku supervised and monitored the protocol. All authors read and approved the final manuscript.

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References

[1] K. R. Smith, "Why both gas and biomass are needed today to address the solid fuel cooking problem in India: A challenge to the biomass stove community," *Energy for Sustainable Development*, vol. 38, pp. 102-103, 2017.

[2] G. Legros, I. Havet, N. Bruce, and S. Bonjour, *The Energy Access Situation in Developing Countries: A Review Focused on Least Developed Countries And Sub-Saharan Africa*, UNDP and World Health Organization, Nairobi, Kenya, 2009.

[3] J. Baumgartner, J. J. Schauer, M. Ezzati et al., "Indoor air pollution and blood pressure in adult women living in rural China," *Environmental Health Perspectives*, vol. 119, no. 10, pp. 1390–1395, 2011.

[4] C. Torres-Duque, D. Maldonado, R. Pérez-Padilla, M. Ezzati, and G. Viegi, "Biomass fuels and respiratory diseases: A review of the evidence," *Proceedings of the American Thoracic Society*, vol. 5, no. 5, pp. 577–590, 2008.

[5] C. L. Ranabhat, C.-B. Kim, C.-S. Kim, N. Jha, K. C. Deepak, and F. A. Connel, "Consequence of indoor air pollution in rural area of Nepal: A simplified measurement approach," *Frontiers in Public Health*, vol. 3, article no. 5, 2015.

[6] K. L. Dionisio, S. R. C. Howie, F. Dominici et al., "The exposure of infants and children to carbon monoxide from biomass fuels in the Gambia: A measurement and modeling study," *Journal of Exposure Science and Environmental Epidemiology*, vol. 22, no. 2, pp. 173–181, 2012.

[7] D. G. Fullerton, N. Bruce, and S. B. Gordon, "Indoor air pollution from biomass fuel smoke is a major health concern in the developing world," *Transactions of the Royal Society of Tropical Medicine and Hygiene*, vol. 102, no. 9, pp. 843–851, 2008.

[8] L. P. Naeher, M. Brauer, M. Lipsett et al., "Woodsmoke health effects: A review," *Inhalation Toxicology*, vol. 19, no. 1, pp. 67–106, 2007.

[9] Y. Ramesh Bhat, N. Manjunath, D. Sanjay, and Y. Dhanya, "Association of indoor air pollution with acute lower respiratory tract infections in children under 5 years of age," *Paediatrics and International Child Health*, vol. 32, no. 3, pp. 132–135, 2012.

[10] N. Z. Janjua, B. Mahmood, V. K. Dharma, N. Sathiakumar, and M. I. Khan, "Use of biomass fuel and acute respiratory infections in rural Pakistan," *Public Health*, vol. 126, no. 10, pp. 855–862, 2012.

[11] E. T. Taylor and S. Nakai, "Prevalence of acute respiratory infections in women and children in western sierra leone due to smoke from wood and charcoal stoves," *International Journal of Environmental Research and Public Health*, vol. 9, no. 6, pp. 2252–2265, 2012.

[12] S. Jackson, K. H. Mathews, D. Pulanić et al., "Risk factors for severe acute lower respiratory infections in children - a systematic review and meta-analysis," *Croatian Medical Journal*, vol. 54, no. 2, pp. 110–121, 2013.

[13] E. D. S. Van Vliet, K. Asante, D. W. Jack et al., "Personal exposures to fine particulate matter and black carbon in households cooking with biomass fuels in rural Ghana," *Environmental Research*, vol. 127, pp. 40–48, 2013.

[14] Central Statistical Agency (CSA) [Ethiopia] and ICF, Ethiopia Demographic and Health Survey 2016. 2016: Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF.

[15] M. Alemayehu, K. Alemu, H. R. Sharma, Z. Gizaw, and A. Shibru, "Household fuel use and acute respiratory infections in children under five years of age in Gondar city of Ethiopia," *Journal of Environment and Earth Science*, vol. 4, no. 7, 2014.

[16] H. Sanbata, A. Asfaw, and A. Kumie, "Association of biomass fuel use with acute respiratory infections among under- five children in a slum urban of Addis Ababa, Ethiopia," *BMC Public Health*, vol. 14, no. 1, article no. 1122, 2014.

[17] T. Tafese and B. Tamre, "Household energy choice and demand in urban Ethiopia: case of Wolaita zone," *International Journal of Research in Commerce, Economics & Management*, vol. 5, no. 11, pp. 5–10, 2015.

[18] V. Mishra, "Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe," *International Journal of Epidemiology*, vol. 32, no. 5, pp. 847–853, 2003.

[19] D. N. Sikolia, K. Mwololo, H. Cherop et al., "The Prevalence of acute respiratory infections and the associated risk factors: a study of children under five years of age in Kibera Lindi Village, Nairobi, Kenya," *Journal of the National Institute of Public Health*, vol. 51, no. 1, pp. 67–72, 2002.

[20] Central Statistical Agency [Ethiopia] and ICF International, Ethiopia Demographic and Health Survey 2011. 2012: Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International.

[21] WHO, *Acute Respiratory Infections in Children: Case Management in Small Hospitals in Developing Countries: A Manual for Doctors and Other Senior Health Workers*, 1990.

[22] M. Dherani, D. Pope, M. Mascarenhas, K. R. Smith, M. Weber, and N. Bruce, "Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: A systematic review and meta-analysis," *Bulletin of the World Health Organization*, vol. 86, no. 5, pp. 390–394, 2008.

[23] M. L. Clark, S. J. Reynolds, J. B. Burch, S. Conway, A. M. Bachand, and J. L. Peel, "Indoor air pollution, cookstove quality, and housing characteristics in two Honduran communities," *Environmental Research*, vol. 110, no. 1, pp. 12–18, 2010.

[24] A. M. Taksande and M. Yeole, "Risk factors of Acute Respiratory Infection (ARI) in under-fives in a rural hospital of Central India," *Journal of Pediatric and Neonatal Individualized Medicine*, vol. 5, no. 1, Article ID e050105, 2016.

[25] F. Ujunwa and C. Ezeonu, "Risk factors for acute respiratory tract infections in under-five children in Enugu Southeast Nigeria," *Annals of Medical and Health Sciences Research*, vol. 4, no. 1, p. 95, 2014.

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Household fine particulate matter ($PM_{2.5}$) concentrations from cooking fuels: the case in an urban setting, Wolaita Sodo, Ethiopia

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Abstract

Household air pollution from biomass fuel is a main cause of health problem in Ethiopia, since 93% of households use solid fuel for cooking. Household air pollution studies are limited in Ethiopia. Therefore, we attempted to determine the level of household fine particulate matter concentrations from cooking fuels in Wolaita Sodo town, Ethiopia. A cross-sectional study design was used to measure particulate matter ($PM_{2.5}$) in 109 kitchens in randomly selected households. The University of California Berkeley particle monitor data logger devices were used for measuring the level of $PM_{2.5}$ for the duration of 24 h based on the installation protocol. Descriptive statistics were used to evaluate the variation across fuel sources. Out of 109 households, 83 (76.15%) and 26 (23.85%) used predominately biomass fuel and mixed types fuel sources for cooking respectively. The overall geometric mean of $PM_{2.5}$ was 413.27 $\mu g/m^3$. The magnitude of $PM_{2.5}$ from biomass fuel source was a mean (SD) of 926.34 $\mu g/m^3$(899.00), followed by mixed type of fuel users, 279.42 $\mu g/m^3$ (216.71). The median concentration of $PM_{2.5}$ in all monitored households was 412.55 $\mu g/m^3$. One-way ANOVA between fuel types was found to be statistically significant resulted in different mean concentration of particulate matter for both types of fuels used in households [$P < 0.001$]. $PM_{2.5}$ was higher than the World Health Organization air quality guideline value. Therefore, supplying improved cook stoves and clean fuel sources is decisive intervention.

Keywords Household air pollution · Fine particulate matter · Fuel type · Cooking fuel · Time spent

Introduction

Globally, more than 3 billion people are still relying on polluting fuels for cooking, lighting, and heating. Household air pollution is attributable to the death of 3.8 million people (WHO 2018). Women and young children, who spend much time near to cooking stoves, are highly exposed (WHO 2018). People in developing countries are commonly exposed to very high levels of pollution for about 3–7 h daily over many years (Ranabhat et al. 2015).

Household air pollution is a major public health threat in developing countries requiring greatly increased efforts in the areas of research and policy-making. The high proportion of solid cook fuel use has been known to result in exposures to multiple toxic products due to incomplete combustion (Legros et al. 2009). This incomplete combustion emitted a sum of all microscopic solid and liquid particles, of human and natural origin, that remain suspended in a medium such as air for some time. These particles vary greatly in size, composition, and origin. Particulate matter less than aerodynamic diameter 2.5 μm ($PM_{2.5}$) is health treating particulate matter (WHO 2005, 2006).

In India, it is also recognized that the health burden from air pollution exposures that primarily occur in the rural indoors due to the incomplete combustion of solid fuels (Balakrishnan et al. 2011). Acute respiratory infection in children (Admasie

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et al. 2018b) and child size at birth (Admasie et al. 2018a) was linked to the type of fuel sources in the households of Ethiopia and can be considered as a neglected health burden in the country.

Exploratory study in Palwal District, Haryana, India, provides preliminary data on the kitchen area assessed during cooking events were emitted $PM_{2.5}$ concentrations of mean 468 μg/m^3(Mukhopadhyay et al. 2012). In rural households of India, the mean of 24-h kitchen area concentration of $PM_{2.5}$ in solid cook fuel using households was 609 μg/m^3 which concludes that fuel type, kitchen type, ventilation, geographical location, and cooking duration were found to be significant predictors of $PM_{2.5}$ concentrations in the household (Balakrishnan et al. 2013). The level of household air pollutants is influenced by outdoor levels, indoor sources, the rate of exchange between indoor and outdoor air, and the characteristics and furnishings of buildings. It also subjected to geographical, seasonal, and diurnal variations .

A study to estimate the exposure of $PM_{2.5}$ for children in Gambia revealed that exposure was highest among children who lived in homes that used firewood (144 μg/m^3 as their main fuel) compared with those who used charcoal (85 μg/m^3) and concluded that children in Gambia have relatively high $PM_{2.5}$ exposure (Dionisio et al. 2012b). In Ghana, to examine cooking practices and kitchen area exposures to fine particulate matter ($PM_{2.5}$) in cooks that using biomass fuel in 29 households, the mean 24-h integrated concentrations in the kitchen area were 446.8 μg/m^3(Van Vliet et al. 2013).

Ethiopia is a country which 84% of the population is found in rural areas with limited access to electric power for cooking foods and lighting. Biomass fuel is exclusively used for cooking foods and heating houses. The housing design and structures in Ethiopia are not meant in ways that can exhaust household air pollutants (Kumie et al. 2009). Hence, incomplete combustion of these fuels and poor ventilation result in high indoor concentrations of health-damaging pollutants.

A magnitude of household air pollution from cooking fuel use in slum areas of Addis Ababa had been assessed in a 24-h measurement of fine particulate matter ($PM_{2.5}$) in 59 houses. The result revealed with geometric mean and standard deviation of 818 ± 3.61 μg/m^3. But based on the type of cooking fuel sources, predominately solid fuel was the highest concentration, 1134 ± 3.36 μg/m^3, followed by kerosene, 637 ± 4.44 μg/m^3, and the least was clean fuel sources, 335 ± 2.51 μg/m^3 (Sanbata et al. 2014a, 2014b). Another study in Bonga, Ethiopia, reported that the average amount of $PM_{2.5}$ in 12 traditional houses in 24-h duration was a mean of 22.1 (± 19.1) μg/m^3 (Pennise et al. 2009).

Level of household air pollution is influenced by the type of cooking fuel, cooking practice, time spent on cooking, and ventilation conditions. However, level of pollution is expected to be higher, the concentration of these household air pollutants is unknown, not regularly monitored, monitoring time was short durations, and few studies were focused on Addis Ababa. Consequently, filling this gap is quite helpful to design appropriate policies and interventions that will help to tackle the challenge. Therefore, the purpose of this study was to determine the level of household fine particulate matter ($PM_{2.5}$) concentrations from cooking fuels in Wolaita Sodo, Ethiopia.

Methods and materials

Study context

The data collection was conducted from December 2017–February 2018 in Wolaita Sodo town, which is situated 329 km from Addis Ababa, Ethiopia. Wolaita Sodo town is located at 6° 49′ N latitude and 39° 47′ E longitude and at an altitude of about 1900 m above sea level. According to the 2016 Wolaita zone health bureau report (Wolaita zone Health Bureau 2016), the town has three sub-cities and 11 Kebeles (the lowest level administrative hierarchy). Based on the 2018 Population Projection by the Central Statistics Agency (CSA) of Ethiopia, the town has a total population of 254,294, of whom 125,855 are men and 128,439 are women (Central Statistical Agency 2018). Detailed study settings were described in studies of Admasie et al. (2018a, 2018b); Tafese and Tamre (2015).

Study design and population

A cross-sectional study design was used to assess the level and characteristics of household $PM_{2.5}$ emissions. Households in the selected Kebeles that used primarily biomass fuel, charcoal, and electric stoves for cooking purpose were included in this study. Mothers were available during the survey and monitoring time. Households with inconvenient kitchen for monitoring devices were excluded.

Sample size and sampling techniques

The sample size of the households were calculated using confidence interval estimates from sample standard deviation, considering a recent study conducted in Gambia. Based on the measurement result, the mean and standard deviation of $PM_{2.5}$ exposures for all subjects were 135 ± 38 μg/m^3 (Dionisio et al. 2012a). The sample size was calculated by assumptions of 95% confidence interval and the standard deviation of the outcome of interest. Estimated by the sample standard error, a 5% precision of mean was considered to get a sample size of 109. Among three sub-cities in the town, two sub-cities were selected randomly. Six Kebeles were selected in these sub-cities. Sampled households were allocated based on probability proportional to the size of the households in each Kebele. Each household was selected using systematic random sampling technique. Households were selected using systematic random sampling techniques.

Operational definition

Mixed fuel users Households which are using both biomass and clean fuels (electricity, liquefied petroleum gas, natural gas, and biogas), but dominantly biomass fuel users.

House ventilation Poor ventilation (a house with only one room, one door, and no or only one window), moderate ventilation (a house with two rooms, two doors, and two windows), and good ventilation (a house with three or more rooms, doors, and windows).

Data collection tools and procedures

Two phases of data collection procedures were applied. The first phase was to collect data on baseline information such as socio-demographic variables, the exposure-related questions, fuel use, stove type, housing characteristics, type of kitchen, cooking practice, cigarette smoking history, occupational history, and medical history.

The second phase was $PM_{2.5}$ monitoring. Household owners were informed about the measurement protocol (University of California-Berkeley 2005) (i.e.,duration, measurement episodes, safety or precaution, starting time, ending time, sounds and lighting of equipment). Meanwhile, observation was conducted on activity pattern, structure of the house and kitchen, ventilation factors, and type of fuels used for cooking. Monitoring equipment was installed for 24 h in the kitchen. Measurement was conducted in the condition of routine cooking practice, or the cook was not insisted to cook without their schedule.

The $PM_{2.5}$ was measured using optical analyzer of the University of California Barkley particle monitor (UCB-PM). It is a portable and battery-operated device. Monitoring was done based on the device's standard operating procedures. The UCB-PM has software designed to its purpose (Smith 2010; University of California-Berkeley 2005). The UCB particle monitor is not a new device, rather it was used for monitoring of particulate matter ($PM_{2.5}$) in a 24-h duration in different countries for the research purpose since 2005 (Arnez et al. 2008; Pennise et al. 2009; Sanbata et al. 2014b). Monitoring in selected kitchens was conducted for 24 h at logging interval of 1min, with sampling of every 30 s. The results were reported in the units of micrograms per cubic meter of air, $\mu g/m^3$. Five UCB-PM loggers were used; one is reserved for control, while other four were for monitoring purpose for devices. The UCB-PMs were produced and calibrated in the household air pollution laboratory at the University of California-Berkeley. The chamber of the photoelectric detector was cleaned with isopropyl alcohol after sampling of every ten households.

Particle monitoring equipment was positioned in kitchens in accordance with the standard placement protocols. The device was placed approximately 100 cm away from the edge of the combustion zone (the edge of the active cooking stove); at a height of 145 cm above the floor (this height relates to the approximate breathing zone of a standing woman); and at least 150 cm away (horizontally) from any openable doors and windows (University of California Berkeley 2005) (Fig. 1).

One supervisor and two environmental health professional data collectors were recruited. Two days of training on the content of the questionnaire, how to approach household owners and how to measure pollutants in the house were provided. Each data collector did 5–7 pretests to check the data collection procedures. The supervisor and principal investigator supervised the completeness, accuracy, and consistency of data. The filled questionnaire and air sampling formats were collected and signed after it was checked for any missing value, correctness, and consistency.

Data quality assurance

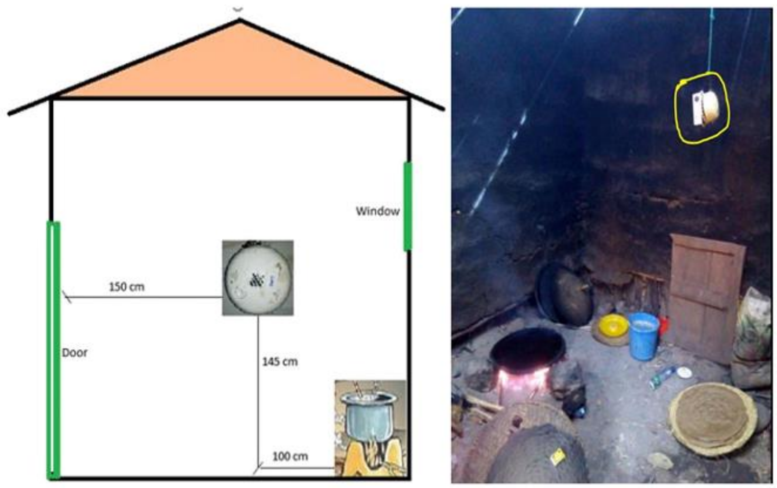
Houses were labeled with a unique code number and the code was recorded on the questionnaire and air sampling format. Regular supervision and follow-up were made by the principal investigator. Training was given to data collectors about how to mounting and uninstalling the monitoring devices in the kitchen. All monitoring devices were calibrated at the manufacturing places before shipping to Ethiopia. UCB-PM devices were validated by the Ultrasonic Personal Aerosol Sampler (UPAS). UPAS devices are working in gravimetric analysis of the mass of particulate matters. It was measured in a data quality test schedule with similar setting and standard operating procedures (SOP). The results were compared with each other devices. The concentration of UCB-PM was higher than that of the UPAS data. Hence, a coefficient factors was developed. The values of UCB-PM were multiplied by the correction factor to get the estimation.

UCB PM correction factor

$$= \frac{\text{UPAS PM}_{2.5}\text{Concentration}\left({}^{\mu g}/_{m^3}\right)}{\text{UCB PM PM}_{2.5}\text{Concentration}\left({}^{\mu g}/_{m^3}\right)}$$

Daily configuration before and after sampling was done according to the protocol. The SOPs of the instruments were

Fig. 1 Placement position of particulate matter monitoring device in the kitchen area



Drawing: Amha Admasie

Photo: Amha Admasie, 18-Dec-2017: Time 10:17AM

strictly followed for the conduct of the research activities. Data sheet used to record the household code and address, date and time of start, devices code, date and end time, and any remarks during the monitoring duration. Daily backup of stored data into the computer program from all loggers was done. To check consistencies of each device, 24-h time weighted average concentrations of each UCB-PM devices were compared with each other in the same kitchen at the same time. The value of Cronbach's alpha (α) for all devices was 0.976 and the Pearson correlation coefficients of each device against the other ranges from 0.75 to 0.98.

Data management and analysis

The collected data was checked, cleaned, coded, and entered into computer software program for analysis, in Epi Info 7.1.2.0, SPSS 20 and the $PM_{2.5}$ data were downloaded to UCB Monitor Manager software (Version 2.1.3). Kolmogorov-Smirnov and Shapiro-Wilk arithmetic test of normality were checked and later the data was transformed to logarithm. Mean, standard deviation, median, percentiles, minimum and maximum values, and analysis of variance (ANOVA) for different fuel sources were analyzed. The correlation test between categorical variables and level of concentrations of particulate matter was analyzed using the "eta statistics." The level of $PM_{2.5}$ data was compared with the World Health Organization (WHO) Air Quality Guideline (AQG) values.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Results

Households were classified into two categories based on the type of fuels used for cooking. Out of 109 households, 83 (76.15%) were biomass fuel users, the remaining 26 (23.85%) were mixed type fuel users for cooking.

Sociodemographic characteristics

The type of fuel used for cooking was significantly associated at *P* value < 0.05 with mothers' education level, employment status of mothers', monthly income of the household, and house ownership (Table 1).

Cooking place characteristics

The type of fuel used for cooking was significantly associated at *P* value < 0.05 with number of rooms, doors, and windows of the house, type of stoves used, and level of house ventilation while cooking place, time spent in cooking, and baking bread/injera were not significantly associated with type of fuel used for cooking (Table 2).

Concentration of $PM_{2.5}$

The geometric mean concentration of $PM_{2.5}$ in all monitored households was 413.27 μg/m^3. The arithmetic mean of $PM_{2.5}$ in all monitored households was 772.03 μg/m^3 (SD = 837.39) with 95% CI 613.04, 931.01. The magnitude of $PM_{2.5}$ was different for different fuel sources, which was higher in biomass fuel users accounting 926.34 μg/m^3 (SD = 899.00) and followed by mixed type of fuel users which accounted to

Table 1 Relationship between sociodemographic variables and type of fuels for cooking, Wolaita Sodo, Ethiopia, 2018

Sociodemographic variables		Type of fuel for cooking		Total	Chi-squared (*P* value)
		Biomass	Mixed		
Education status	No Education	1 (4.8)	20 (95.2)	21 (19.3)	22.69 (< 0.001)
	Primary level	4 (11.1)	29 (88.9)	36 (33)	
	Secondary level	4 (20.0)	16 (80.0)	20 (18.3)	
	Higher level	17 (53.1)	15 (46.9)	32 (29.4)	
Employment status	Employed	13 (48.1)	14 (51.9)	27 (24.8)	12.31 (0.006)
	Petty trade	4 (18.2)	18 (81.8)	22 (20.2)	
	Unemployed	4 (21.1)	15 (78.9)	19 (17.4)	
	Housewife	5 (12.2)	36 (87.8)	41 (37.6)	
Family size	≤ 5 Families	17 (22.7)	58 (77.3)	75 (68.8)	0.186 (0.666)
	> 5 Families	9 (26.5)	25 (73.5)	34 (31.2)	
Monthly income for the household	< 1000 Birr	2 (6.3)	30 (93.7)	32 (29.4)	48.35 (< 0.001)
	1000–3000 Birr	3 (8.3)	33 (81.7)	36 (33)	
	3001–5000 Birr	5 (22.7)	17 (77.3)	22 (20.2)	
	> 5000 Birr	16 (84.2)	3 (15.8)	19 (17.4)	
House ownership	Own house	21 (32.3)	44 (67.7)	65 (59.6)	6.33 (0.012)
	Rent house	5 (11.4)	39 (88.6)	44 (40.4)	

279.42 μg/m^3 (SD = 216.71). The median concentration of $PM_{2.5}$ in all monitored households was 412.55 μg/m^3. In the mixed type of fuel use, the electric stove users were contributed in reduction of household air pollution. One-way ANOVA between fuel types was found to be statistically significant resulted in different mean concentration of particulate matter for both type of fuels used in households [$F(1, 107) = 13.44$, $P = 0.000$] (Table 3).

A 24-h mean $PM_{2.5}$ concentration was presented in boxplot graph. The graph indicated that the biomass fuel users had a

Table 2 Relationship between house and kitchen characteristics with types of stoves in Wolaita Sodo, Ethiopia, 2018

House and kitchen variables (*n* = 109)		Type of cooking fuels		Total	(Chi-square) *P* value
		Biomass	Mixed		
Number of rooms of the house	1 room	18 (90)	2 (10)	20 (18.3)	5.69 (0.058)
	2 rooms	32 (82.1)	7 (17.9)	39 (35.8)	
	3 + rooms	33 (66)	17 (34)	50 (45.9)	
Number of doors of the house	1 door	30 (93.7)	2 (6.3)	32 (29.4)	15.01 (0.001)
	2 doors	27 (84.4)	5 (15.6)	32 (29.4)	
	3 + doors	26 (57.8)	19 (42.2)	45 (41.3)	
Number of windows of the house	1 window	32 (94.1)	2 (5.9)	34 (31.2)	30.61 (0.000)
	2 windows	31 (93.9)	2 (6.1)	33 (30.3)	
	3 + windows	20 (47.6)	22 (52.4)	42 (38.5)	
Cooking place	Inside the house	37 (67.3)	18 (32.7)	55 (50.5)	4.81 (0.028)
	Separate kitchen	46 (85.2)	8 (14.8)	54 (49.5)	
Type of stoves	Open stove	78 (89.7)	9 (10.3)	87 (79.8)	43.30 (0.000)
	Improved	5 (22.7)	17 (77.3)	22 (20.2)	
Time spent in cooking	1 h	12 (70.6)	5 (29.4)	17 (15.6)	3.47 (0.176)
	2 h	49 (83.1)	10 (16.9)	59 (54.1)	
	≥3 h	22 (66.7)	11 (33.3)	33 (30.3)	
Baking injera	Yes	67 (74.4)	23 (25.6)	90 (82.6)	0.82 (0.364)
	No	16 (84.2)	3 (15.8)	19 (17.4)	
Level of house ventilation	Poor	37 (97.4)	1 (2.6)	38 (34.86)	14.96 (0.001)
	Moderate	22 (68.7)	10 (31.3)	32 (29.35)	
	Good	24 (51.5)	15 (38.5)	39 (35.77)	

Table 3 Average magnitude of particulate matter, $PM_{2.5}$ ($\mu g/m^3$), in households of Wolaita Sodo, Ethiopia, 2018

Statistics	All types of fuels	Biomass	Mixed
No. of HHs (% of total)	109 (100%)	83 (76.14%)	26 (23.9%)
Arithmetic mean (SD)	772.03 (837.39)	926.34 (899.00)	279.42 (216.71)
95% CI for the mean	(613.04, 931.01)	(730.04, 1122.64)	(191.88, 366.95)
Geometric mean	413.27	531.49	185.12
Median	412.55	589.97	230.90
Maximum	4161.82	4161.82	928.15
Minimum	5.50	5.50	5.50
Range	4156.32	4156.32	922.65
25th percentiles	189.15	240.82	117.07
75th percentiles	1085.94	1355.47	388.05
95th percentiles	2622.94	2821.37	823.36

higher mean of particulate matter than the mixed type of fuel users (Fig. 2).

The 24-h mean $PM_{2.5}$ concentrations were varied according to the number of doors and windows of the house, it was least in more than three door and three window houses than one door and one window houses, respectively. Those who used a separate kitchen for cooking showed slightly higher concentration of $PM_{2.5}$ than those who used inside the house. Improved stoves had lower emissions than the open stoves. Those who spent 3 h or more in cooking indicated higher emissions of $PM_{2.5}$ than spending 2 h or less in cooking. As to the level of house ventilation, adequately ventilated houses showed least emissions of $PM_{2.5}$ than moderately or poorly ventilated houses. The correlation test between variables and level of concentrations of particulate matter was analyzed using the "Eta statistics." The Eta square is to explain the level of concentration in terms of a given variable. Based on these, all variables were poorly associated with the level of particulate matter. Therefore, the Eta values for all variables were close to zero indicating no strong association between these variables (Table 4).

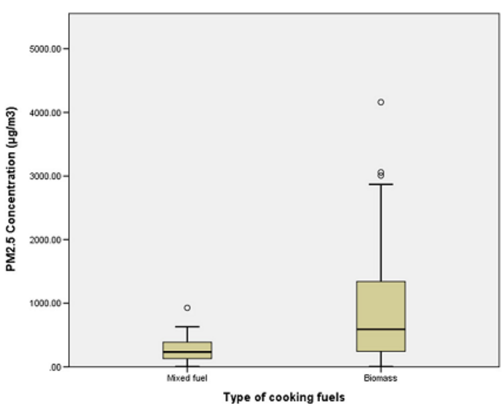


Fig. 2 A boxplot showing mean concentration of $PM_{2.5}$ in different fuel types for cooking, Wolaita Sodo, Ethiopia, 2018

Discussion

The overall geometric mean of the of $PM_{2.5}$ in Wolaita Sodo town households was 413.27 $\mu g/m^3$, while the arithmetic mean (SD) concentration of $PM_{2.5}$ was 772.03 $\mu g/m^3$(837.39). The magnitude of $PM_{2.5}$ was different for different fuel sources, the highest was among biomass fuel users, 531.49 $\mu g/m^3$ and followed by mixed fuel users, 185.12 $\mu g/m^3$.

According to the WHO AQG values, $PM_{2.5}$ for 24-h geometric mean level in houses should not exceed 25 $\mu g/m^3$ (WHO 2005, 2006); WHO Interim Target-1 (IT-1) is 75 $\mu g/m^3$, WHO Interim Target-2 (IT-2) is 50 $\mu g/m^3$, and WHO Interim Target-3 (IT-3) is 37.5 $\mu g/m^3$ (WHO 2005, 2006). Our study result indicated excessively higher than the WHO air quality guideline values and the WHO IT-1, IT-2, and IT-3 values. The geometric mean concentration level of biomass fuel users was 531.49 $\mu g/m^3$, which was 21 times higher than the WHO AQG values of a 24-h mean level, and the mixed type of fuel users was 185.12 $\mu g/m^3$, which was sevenfold higher than the WHO AQG values for a 24-h mean level. Domestic household air quality levels associated with biomass fuel combustion in Nepal exceeded WHO household air quality standards and are in the hazardous range for human health (Bartington et al. 2017). In Nablus city of West Bank, Palestine, the annual averages of $PM_{2.5}$ concentrations were found to be at least three times higher than that of the European Air Quality Standards in indoors (Jodeh et al. 2018).

This study was compared with a study conducted in Shero-Meda area of Addis Ababa, Ethiopia, revealed that the 24-h particulate matter levels in the kitchens at an average of 1580 $\mu g/m^3$ with a geometric mean (SD) of 793.38 (1580) $\mu g/m^3$; all households exceeded the United States

Table 4 A 24-h $PM_{2.5}$ concentrations in relation to house and kitchen variables, Wolaita Sodo, Ethiopia, 2018

House and kitchen variables		Total	$PM_{2.5}$ ($\mu g/m^3$)		Eta test	
			Mean	SD	Eta value	Eta square
Number of doors of the house	1 door	32	741.33	762.61	0.171	2.92%
	2 doors	32	983.82	1027.82		
	≥ 3 doors	45	643.25	718.94		
Number of windows of the house	1 window	34	754.37	743.59	0.228	5.19%
	2 windows	33	1038	1026		
	≥ 3 windows	42	577.02	695.44		
Type of fuel	Mixed	26	279.42	216.71	0.331	10.95%
	Biomass fuel	83	926.34	899.00		
Cooking place	Inside the house	55	653.77	775.37	0.143	2.04%
	Separate kitchen	54	892.47	887.18		
Type of stoves	Open-fire stove	87	873.41	893.05	0.242	5.85%
	Improved/electric	22	371.11	359.46		
Time spent in cooking	1 h	17	732.53	772.75	0.023	0.0%
	2 h	59	772.68	843.67		
	≥ 3 h	33	791.20	881.34		
Level of house ventilation	Poor	38	904.56	959.26	0.142	2.01%
	Moderate	32	793.81	735.62		
	Good	39	625.02	784.47		

Environmental Protection Agency standard of 35 $\mu g/m^3$ (Megan 2011), the Shiro-Meda area in Addis Ababa is known to use biomass fuels (particularly tree leaves which has higher smoke and the area is known for its low living standard as compared with other areas in the city. Similar study showed in Ethiopia (Bonga and Kebribeyah refugee camps), the 24-h $PM_{2.5}$ was 1250 $\mu g/m^3$ (Pennise et al. 2009). The reason could be Bonga and Kebribeyah are refugee camps which could use exclusively biomass fuels for cooking. Our measurements of a 24-h $PM_{2.5}$ were compared with local study conducted in slum neighborhoods of Addis Ababa city, indicated that the geometric mean was 818 $\mu g/m^3$ (solid fuel = 1134 $\mu g/m^3$, kerosene = 637 $\mu g/m^3$, and clean fuel = 335 $\mu g/m^3$) (Sanbata et al. 2014b).

A state and national household concentration from solid cook fuel use in India, a mean level was ranged from 163 $\mu g/m^3$ in the living area to 609 $\mu g/m^3$ in the kitchen area (Balakrishnan et al. 2013). The justification for being higher concentration in these study areas was due to the study period, sample size, socioeconomic, and type of devices measured in different areas. In the previous periods, particulate matter in general household air pollution was expected to be higher than the current, since the urbanization and modernization lead to the use of clean fuel sources for cooking purpose. However, the study setting in India was a state and national level which hardly to compare with the current study. But, our study had slightly lower emissions as compared with a study in rural Ghana households cooking with a mean biomass fuels of 446.8 $\mu g/m^3$ (Van Vliet et al. 2013); it can be explained that however Ghana is considered more developed than Ethiopia, but this study was conducted in rural setting and in a small sample size at 36 households. Similarly, in Hong Kong, the average concentrations of $PM_{2.5}$ were 25.3 ± 15.0 $\mu g/m^3$ in summer and 34.2 ± 19.0 $\mu g/m^3$ in winter, respectively. There were ~ 50.3% of households exceeding the WHO indoor air quality standard (Tong et al. 2018). But in Nigeria, firewood-exclusive user households resulting a median indoor $PM_{2.5}$ level were 1414.4 $\mu g/m^3$ [interquartile range, 831.2–3437.0] (Oluwole et al. 2013).

A research conducted in Peru showed that the type of fuel used to cook had a significant effect on kitchen concentrations of $PM_{2.5}$ in Peru (Helen et al. 2015). This indicating that the study area used other fine particulate matter emitting activities and may use polluting fuels exclusively; moreover, the study area was more populated and living in slum areas.

In a similar study, significantly higher concentration was reported in the rural village of the district of Hajar of Haryana state, India, to predict exposure levels of respirable $PM_{2.5}$ for the cook from combustion of cooking fuels in a 24-h measurement indicating a varied concentration from 4.69 $\mu g/m^3$ for gas/LPG stove to 11,000 $\mu g/m^3$ for dung cake/Chula (Joon et al. 2011), but separately for the gas, wood/Chulah, the crop residue/Chulah, dung cake/Challah, and mix fuel/Chulah were 25.67 $\mu g/m^3$, 222.69 $\mu g/m^3$, 393.39 $\mu g/m^3$, 774.52 $\mu g/m^3$ and 376.40 $\mu g/m^3$ respectively. The discrepancy was extremely large as compared with our study with the maximum reported concentration of 2408.30 $\mu g/m^3$ for the biomass fuel. This could be due to the fact that Indian communities were more rural setting than our study settings. Moreover, in our study, dung cake was not a primary fuel source which has a potential to emit large concentrations of particulate matter as compared with other biomass fuel sources since our study is in a semi-urban setting. Similarly, our study was reported lower concentration than the modeling study of household air pollution from cook stove emissions in developing countries using a Monte Carlo single-box model, the mean modeled 24-h concentration for $PM_{2.5}$ was 1975 $\mu g/m^3$ (median = 1320 $\mu g/m^3$) (Johnson et al. 2011). This modeling was not a direct method of measuring particulate matter concentration, instead it used a proxy factors to estimate approximate measurements. Hence, it could have significant variations with the actual measurement.

The limitation of this study was that the measurement was a onetime measurement which was unable to consider seasonal pattern; the particulate matter was measured only in optical measurement devices, which needs to be supported in a gravimetric analysis. Meanwhile, the study linking between particulate matter pollution with specific health outcomes in the households was limited.

Conclusion

The current concentration of $PM_{2.5}$ was by far exceeded the WHO AQG values. The levels of concentration from biomass fuel were higher than mixed fuel sources. Therefore, short-term action plan: supplying improved cook stoves, biogas technology, solar power, and liquefied petroleum gas to low income households with government financial subsidy and long-term loan, awareness on house ventilation; while in the long-term action: sustainable demand-oriented electrification system supply and clean energy intervention to all households are mandatory.

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Authors' contributions AA carried out protocol development, data collection, data management and analyses, and writing the manuscript. AK and AW were involved in protocol development, providing field work monitoring, and editing the manuscript. WT was involved on technical support of monitoring devices and editing manuscript. All authors read and approved the manuscript.

Compliance with ethical standards

Ethical approval and consent to participate Ethical clearance to undertake the study was obtained from Addis Ababa University, College of Health Sciences-Institutional Review Board Office. Informed consent to participate in the study was obtained. For this, subject information sheet and informed consent letter were attached to each questionnaire. Participants were informed that participating is voluntarily and has no risk or harm. The right of the respondent to withdraw from the interview or not to participate was respected. For those houses with poorly ventilated houses and biomass-dependent households were informed about the health risks of poor house ventilation and biomass fuel use.

Competing interests The authors declare that they have no conflict of interest.

References

Admasie A, Kumie A, Worku A (2018a) Association of household fuel type, kitchen characteristics and house structure with child size at birth in Wolaita Sodo, Southern Ethiopia. Open Public Health J 11: 298–308. https://doi.org/10.2174/1874944501811010298

Admasie A, Kumie A, Worku A (2018b) Children under five from houses of unclean fuel sources and poorly ventilated houses have higher odds of suffering from acute respiratory infection in Wolaita-Sodo, Southern Ethiopia: a case-control study. J Environ Public Health 2018:9–9. https://doi.org/10.1155/2018/9320603

Amez CA, Edwards Rufus D, Michael J, Miriam Z, Leonora R, Díaz JR et al (2008) Reduction in personal exposures to particulate matter and carbon monoxide as a result of the installation of a Patsari improved cook stove in Michoacan Mexico. Indoor Air 18(2):93–105

Balakrishnan K, Ramaswamy P, Sambandam S, Thangavel G, Ghosh S, Johnson P et al (2011) Air pollution from household solid fuel combustion in India: an overview of exposure and health related information to inform health research priorities. Glob Health Action 4(5638):5638. https://doi.org/10.3402/gha.v4i0.5638

Balakrishnan K, Ghosh S, Ganguli B, Sambandam S, Bruce N, Barnes DF, Smith KR (2013) State and national household concentrations of PM2.5 from solid cookfuel use: results from measurements and modeling in India for estimation of the global burden of disease. Environ Health Perspect 12(77). https://doi.org/10.1186/1476-069X-12-77

Bartington SE, Bakolis I, Devakumar D, Kurmi OP, Gulliver J, Chaube G et al (2017) Patterns of domestic exposure to carbon monoxide and particulate matter in households using biomass fuel in Janakpur, Nepal. Environ Pollut (Barking, Essex : 1987) 220(Pt A):38–45. https://doi.org/10.1016/j.envpol.2016.08.074

Central Statistical Agency (2018) Recent survey releases: new towns population projection. Central Statistical Agency, Addis Ababa, Ethiopia

Dionisio KL, Stephen RCH, Dominici F, Fornace KM, Spengler JD, Donkor S et al (2012a) The exposure of infants and children to carbon monoxide from biomass fuels in The Gambia: a measurement and modeling study. J Expo Sci Environ Epidemiol 22:173–181. https://doi.org/10.1038/jes.2011.47

Dionisio KL, Howie SRC, Ezzati M (2012b) Household concentrations and exposure of children to particulate matter from biomass fuels in The Gambia. Environ Sci Technol 46(6):3519–3527

Helen GS, Aguilar-Villalobos M, Adetona O, Cassidy B, Bayer CW, Hendry R et al (2015) Exposure of pregnant women to cookstove-related household air pollution in urban and Periurban Trujillo, Peru. Arch Environ Occup Health 70(1):10–18. https://doi.org/10.1080/19338244.2013.807761

Jodeh S, Hasan AR, Amarah J, Judeh F, Salghi R, Lgaz H, Jodeh W (2018) Indoor and outdoor air quality analysis for the city of Nablus in Palestine: seasonal trends of PM10, PM5.0, PM2.5, and PM1.0 of residential homes. Air Qual Atmos Health 11(2):229–237

Johnson M, Lam N, Brant S, Gray C, Pennise D (2011) Modeling indoor air pollution from cookstove emissions in developing countries using a Monte Carlo single-box model. Atmos Environ 45:3237–3243

Joon V, Kumari H, & Chandra A (2011) Predicting exposure levels of respirable particulate matter (PM2.5) and carbon monoxide for the cook from combustion of cooking fuels. Paper presented at the International Conference on Chemistry and Chemical Process, Singapore

Kumie A, Emmelin A, Wahlberg S, Berhane Y, Ali A, Mekonnen E, Brandstrom D (2009) Magnitude of indoor NO2 from biomass fuels in rural settings of Ethiopia. Indoor Air 19(1):14–21. https://doi.org/10.1111/j.1600-0668.2008.00555.x

Legros G, Havet I, Bruce N, & Bonjour S (2009) The energy access situation in developing countries: a review focused on least developed countries and sub-Saharan Africa. Nairobi, Kenya

Megan G (2011) Mixed methods approach to assessing indoor air pollution among women in Addis Ababa. (Master of Public Health in Global Health), Emory University, Atlanta. Retrieved from https://legacy-etd.library.emory.edu/view/record/pid/emory:93n41

Mukhopadhyay R, Sambandam S, Pillarisetti A, Jack D, Mukhopadhyay K, Balakrishnan K et al (2012) Cooking practices, air quality, and the acceptability of advanced cookstoves in Haryana, India: an exploratory study to inform large-scale interventions. Glob Health Action 5:1–13. https://doi.org/10.3402/gha.v5i0.19016

Oluwole O, Ana GR, Arinola GO, Wiskel T, Falusi AG, Huo D et al (2013) Effect of stove intervention on household air pollution and the respiratory health of women and children in rural Nigeria. Air Qual Atmos Health 6(3):553–561

Pennise D, Brant S, Agbeve SM, Quaye W, Mengesha F, Tadele W, Wofchuck T (2009) Indoor air quality impacts of an improved wood stove in Ghana and an ethanol stove in Ethiopia. Energy Sustain Dev 13:71–76

Ranabhat CL, Kim C-B, Kim C-S, Jha N, Deepak KC, Connel FA (2015) Consequence of indoor air pollution in rural area of Nepal: a simplified measurement approach. Front Public Health 3:5. https://doi.org/10.3389/fpubh.2015.00005

Sanbata H, Asfaw A, Kumie A (2014a) Association of biomass fuel use with acute respiratory infections among under- five children in a slum urban of Addis Ababa, Ethiopia. BMC Public Health 14:1122. https://doi.org/10.1186/1471-2458-14-1122

Sanbata H, Asfaw A, & Kumie A (2014b) Indoor air pollution in slum neighbourhoods of Addis Ababa, Ethiopia. Indoor air pollution (IAP) updates from the WASHplus Project. Atmospheric environment

Smith KR (2010) Development of the UCB-L particle monitor: for future California applications in environmental justice; School of Public Health University of California Berkeley, Prepared for the California Air Resources Board and the California Environmental Protection Agency

Tafese T, Tamre B (2015) Household energy choice and demand in urban Ethiopia: case of Wolaita zone. Int J Res Commer Econ Manag 5(11):5–10

Tong X, Wang B, Dai W-T, Cao J-J, Ho SSH, Kwok TCY et al (2018) Indoor air pollutant exposure and determinant factors controlling household air quality for elderly people in Hong Kong. Air Qual Atmos Health 11(6):695–704

University of California Berkeley (2005) Standard operating procedure installing indoor air pollution instruments in a home (Vol. Version 5.1). University of California Berkeley: Indoor Air Pollution Team and Center for Entrepreneurship in International Health and Development (CEIHD) School of public health, University of California Berkeley

University of California-Berkeley (2005) UCB Particle Monitor Protocol (October 2005) Standard Operating Procedure UCB Particle Monitor (Collection, Downloading, and Storage of Data) Version 5.1 (October 2005), Indoor Air Pollution Team and Center for Entrepreneurship in International Health and Development (CEIHD) School of Public Health, University of California-Berkeley USA. University of California, Berkeley USA: Berkeley Air Monitoring Group and Indoor Air Pollution Team School of Public Health, University of California, Berkeley USA

Van Vliet ED, Asante K, Jack DW, Kinney PL, Whyatt RM, Chillrud SN et al (2013) Personal exposures to fine particulate matter and black carbon in households cooking with biomass fuels in rural Ghana. Environ Res 127:40–48

WHO (2005) WHO air quality guidelines global update 2005 report on a working group meeting, Bonn, Germany, 18–20 October 2005: World Health Organization

WHO (2006) WHO Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Copenhagen: World Health Organization, Regional Office for Europe; 2006

WHO (2018) Household air pollution and health. 8 May 2018. from http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

Wolaita Zone Health Bureau (2016) Wolaita zone health bureau annual report. Wolaita Sodo, Ethiopia: Wolaita zone Health Bureau

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Determination of the characteristics, level, and associated factors of Carbon monoxide in households of biomass fuel users

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Abstract:	Background An estimated 90% of the Ethiopian urban households used biomass fuel for cooking. The level of carbon monoxide from polluting fuel studies were limited in Ethiopia. Therefore, the main objective of this study was to determine the level and characteristics of indoor Carbon monoxide in cooking fuel users, in Wolaita Sodo, Ethiopia. Methods A cross-sectional study design was used to monitor the level of carbon monoxide in 24-hour duration using a HOBO CO Logger (model #H11-001, Onset Computer Company, Bourne, MA, USA) in 66 households. Randomly 6 districts were selected among 11 districts. Data were analyzed using Epi Info 7.1.2.0, SPSS 20 and BoxCar Pro software (Version 4.3). Mean, standard deviation, median, and percentiles values were calculated to describe the data. A linear regression model and Analysis of variance was used to compare means of carbon monoxide among biomass fuel and mixed fuels users. The levels of carbon monoxide data were compared with the WHO Air Quality Guideline values and previously conducted studies. Results The concentration of carbon monoxide was monitored in 66 households, but because of poor quality data, 11 household data were discarded. Out of 55 households, 45 (81.8%) biomass fuel users and 10 (18.2%) mixed fuel users. A 24-hour overall mean concentration of carbon monoxide was 14.26 mg/m3 (SD=10.06) with (95% CI 11.54, 16.98). The magnitude was the higher in biomass fuel users accounted to 14.41mg/m3 (SD=10.29) and mixed fuel users, 13.55 mg/m3 (SD=9.41). The median concentration in all households were 10.73 mg/m3. The pearson correlation between type of fuel and carbon monoxide concentration level was -0.182, with p-values 0.185, while ANOVA between fuel types was not statistically significant. Conclusion The concentration of carbon monoxide was double to the WHO air quality guideline values. Therefore, clean fuel supply, use of improved stoves or electric stove, improve house design is encouraged. Clean energy supply to the community can solve the root problem of household air pollution.
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Determination of the characteristics, level, and associated factors of Carbon monoxide in households of biomass fuel users

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ABSTRACT

Background: An estimated 90% of the Ethiopian urban households used biomass fuel for cooking. The level of carbon monoxide from polluting fuel studies were limited in Ethiopia. Therefore, the main objective of this study was to determine the level and characteristics of indoor Carbon monoxide in cooking fuel users, in Wolaita Sodo, Ethiopia.

Methods: A cross-sectional study design was used to monitor the level of carbon monoxide in 24-hour duration using a HOBO CO Logger (model #H11-001, Onset Computer Company, Bourne, MA, USA) in 66 households. Randomly 6 districts were selected among 11 districts. Data were analyzed using Epi Info 7.1.2.0, SPSS 20 and BoxCar Pro software (Version 4.3). Mean, standard deviation, median, and percentiles values were calculated to describe the data. A linear regression model and Analysis of variance was used to compare means of carbon monoxide among biomass fuel and mixed fuels users. The levels of carbon monoxide data were compared with the WHO Air Quality Guideline values and previously conducted studies.

Results: The concentration of carbon monoxide was monitored in 66 households, but because of poor quality data, 11 household data were discarded. Out of 55 households, 45 (81.8%) biomass fuel users and 10 (18.2%) mixed fuel users. A 24-hour overall mean concentration of carbon monoxide was 14.26 mg/m^3 (SD=10.06) with (95% CI 11.54, 16.98). The magnitude was the higher in biomass fuel users accounted to 14.41mg/m^3 (SD=10.29) and mixed fuel users, 13.55 mg/m^3 (SD=9.41). The median concentration in all households were 10.73 mg/m^3. The pearson correlation between type of fuel and carbon monoxide concentration level was -0.182, with p-values 0.185, while ANOVA between fuel types was not statistically significant.

Conclusion: The concentration of carbon monoxide was double to the WHO air quality guideline values. Therefore, clean fuel supply, use of improved stoves or electric stove, improve house design is encouraged. Clean energy supply to the community can solve the root problem of household air pollution.

Key words: Carbon monoxide, concentration, CO level, fuel types, biomass fuel

INTRODUCTION

Around half of the world's population, relies on biomass fuels such as wood, animal dung, and crop residues. A majority of these households are located in poor rural communities and burn such solid fuels in inefficient devices, often in kitchens that are poorly ventilated, resulting in very high exposures to multiple toxic products of incomplete combustion (1). People in developing countries are commonly exposed to very high levels of pollution for 3–7 hours daily over many years (2).

Children, women and elders spend a large of their time indoors, which makes indoor spaces important microenvironments when addressing risks from air pollution. Most of a personal daily exposure to many air pollutants comes through inhalation of indoor air, both because of the amount of time spent indoors and because of the higher pollution levels indoors. Indoor concentrations of air pollutants are influenced by outdoor levels, indoor sources, the rate of exchange between indoor and outdoor air, and the characteristics and furnishings of buildings. Indoor concentrations of air pollutants are subject to geographical, seasonal and diurnal variations (3).

In India it is also recognized that, the health burden from air pollution exposures that primarily occur in the rural indoors due to the incomplete combustion of solid fuels in households is major contributor to the global burden of disease (4). Exploratory study in Palwal District, Haryana, India, provides preliminary data on a 24-hour CO concentrations of kitchen area and kitchen personal CO concentrations was ranged between 0.82 and 5.27 ppm respectively (5).

A study in The Gambia to measure the concentrations of CO from children of under 5 years of age using small, passive, color stain diffusion tubes, with multiple CO measurements to measure day-to-day exposure variability showed that the mean measured CO exposure for 1181 children was 1.04±1.46 ppm, indicating that the Gambian children in this study on average have a relatively low CO exposure. Burning insect coils, using charcoal, and measurement done in the rainy season were associated with higher exposure (3).

Housing characteristics were determined to indicate ventilation that may affect carbon monoxide (CO) (6). A study to assess the relationship of biomass smoke, particulate matter, carbon monoxide, and kitchen characteristics in Burkina Faso indicated that, the majority of households used outdoor kitchens and outdoor stoves. Even though many of the households owned and used more than one type of stove, the traditional three-stone stove was popular one. Windows and doors were generally open most of the day. None of the kitchens or stoves had chimneys. The placement of outdoor kitchens varied, with some located next to a wall, in a partially enclosed area or as a free-standing structure in the courtyard. The mean number of meals cooked on the day of PM and CO monitoring was 1.5 (95 % CI 1.4–1.6) and the mean time spent in the kitchen on the day of monitoring was 2.4hour (95% CI2.2–2.5 hour).The mean 24-hourarea concentration of CO reported in119 households in Burkina was 16.9 ppm (95 % CI 12.3–21.4 ppm) (7).

In communities that heavily rely on solid cook-fuels, household concentration of pollutants can also be a significant contributor to ambient air pollution. As a result, these communities often suffer from elevated indoor and outdoor air pollution. The high prevalence of solid cook fuel use for household energy needs in poor communities of developing countries has been known to result in exposures to multiple toxic products of incomplete combustion and is amongst the leading environmental risk factors contributing to the global burden of disease (8).

Indoor air pollution is a major environmental and health hazard from home using biomass fuel in Addis Ababa (9). Incomplete combustion is a common practice in most households due to inappropriate housing structure and poorly designed stoves. Following this problem, stoves emit high concentration of pollutants routinely throughout cooking. But studies indicating the concentration of carbon monoxide from cooking fuel in developing countries especially in sub Saharan countries are limited. Therefore, the main objective of this study was to determine the level, characteristics and associated factors of household Carbon monoxide and associated factors in cooking fuel users.

METHODS

STUDY CONTEXT

The data collection was conducted from December 2017-February 2018 in Wolaita Sodo, which is situated 329 km from Addis Ababa, Ethiopia. Wolaita Sodo is the administrative capital of Wolaita zone. Geographically it is located at an altitude of about 1900 meter above sea-level. According to the 2016 Wolaita zone health bureau report (10) the town has three sub cities and 18 Kebeles. The number of mothers whose age between 15-49 years old was 3829 and the number of less than five year children was 17,277, the descriptions found in a similar publication (11, 12). Based on the 2018 Population Projection by the CSA, this town has a total population of 254,294, of whom 125,855 are men and 128,439 are women (13)

STUDY DESIGN and POPULATIONS

A Cross-sectional study design was used to assess the level and characteristics of indoor CO resulted from cooking fuel users in the kitchen. Background data was collected prior to the measurement of CO. All households in the selected districts who used primarily biomass fuel, charcoal and electric stoves for cooking purpose were selected using systematic random sampling techniques. Mothers were available during the survey and monitoring time. The type of kitchen which is open air but has no shade for it which was not convenient to use monitoring devices were excluded. Moreover, If the household head refused to install any monitoring equipment in their house/kitchen for any reasons were excluded.

SAMPLE SIZE DETERMINATION

The sample size of the households was calculated using confidence interval estimates from sample standard deviation, considering a study conducted in Addis Ababa, Ethiopia in indoor air quality of 9 households, with the mean and standard deviation of CO for all households were 24.6 ± 11.5 mg/m^3 (14). Based on the above assumption, measurement was taken from 66 households. Study households were selected from six districts among eleven districts randomly. Sampled households were allocated based on Probability proportional to Size of the households in each district. Each household was selected using Systematic Random Sampling technique.

OPERATIONAL DEFINITION

Carbon monoxide: is a colorless, non-irritant, odorless and tasteless toxic gas. It is produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, coal, natural gas and kerosene.

Biomass fuel users: Households using polluting fuels users those using wood, charcoal, crop residues, leaves, straw, cow dung, tree branches for most of the cooking events all the time.

Clean fuel users: Households which are using clean fuels (i.e. electricity, LPG, natural gas and biogas) for cooking purposes.

Mixed fuel users: Households which are using both biomass and clean fuels, but dominantly biomass fuel users.

House ventilation: Poor ventilation (a house with only one room, one door and no or only one window), moderate ventilation (a house with two rooms two doors and two windows), good ventilation (a house with three or more rooms, doors, and windows).

DATA COLLECTION TOOLS AND PROCEDURES

Baseline data (socio-demographic variables, the exposure related questions, fuel use, stove type, housing characteristics, type of kitchen, cooking practice, smoking history, occupational history, and medical history were collected prior to CO monitoring. Household owners were informed about the measurement protocol (duration, measurement episodes, safety or precaution, starting time, ending time, sounds and lighting of equipment etc.) (15). Meanwhile, an observation was conducted for activity pattern, the structure of house and kitchen, ventilation and house and kitchen characteristics. Monitoring equipment was installed for 24-hour in the kitchen.

The CO was measured using a HOBO CO Logger (model #H11-001, Onset Computer Company, Bourne, MA, USA). The devices have their own standard operating procedures, and were strictly followed these procedures. Monitoring in selected kitchens was conducted for 24-hour at logging interval of every 8 seconds. Three CO data loggers were used. This devices were used by the studies (14, 16-18).

Monitoring equipment positioning protocol

Pollutant monitoring equipment was positioned in kitchens in accordance with the standard placement protocols. According to the Center for Entrepreneurship in International Health and Development School of Public Health, University of California Berkeley (UCB), a standard placement protocol of monitoring equipment stated that a device should be placed approximately 100 cm from the edge of the combustion zone (this distance away from the stove approximates the edge of the active cooking area); at a height of 145 cm above the floor (this height relates to the approximate breathing zone of a standing woman); and at least 150 cm away (horizontally) from any openable doors and windows, where possible (8, 19).

DATA COLLECTORS

Data collectors were environmental health professionals. Data collectors will be given two days training on the content of the questionnaire, and how to measure pollutants in the kitchen. Each data collector did 5-7 pre-tests. The principal investigator supervised the completeness, accuracy and consistency of data. The filled questionnaire and air sampling formats were collected and signed after it is checked for any missing value, correctness and consistency.

DATA QUALITY ASSURANCE

Houses were labeled with a unique code number and the code was recorded on the questionnaire and air sampling format. Regular supervision and follow-up were made. Training was given to data collectors about how to mounting and uninstalling the HOBO CO logger devices in the kitchen. All monitoring devices were calibrated at the manufacturing places before shipping to Ethiopia. Daily configuration before and after sampling was done. The standard operating procedures of the instrument (19) was used. Data sheet to record the household code and address, date and time of start, devices code, date and end time, and any remarks during the monitoring duration was used. Daily backup of stored data in to the computer program from all loggers was done. HOBO CO logger devices were compared with each other in the same kitchen at the same time for validation of each device. The value of Cronbach's alpha (α) was 0.976 and the Pearson correlation coefficients of each device against the other ranges from 0.75 to 0.98.

DATA MANAGEMENT AND ANALYSIS

The collected data was checked, cleaned, coded and entered in to computer software program for analysis, in Epi Info 7.1.2.0, SPSS 20 and BoxCar Pro software (Version 4.3). Arithmetic mean, Geometric mean, standard deviation, geometric standard deviation, median, percentiles, minimum and maximum values, were calculated. A linear regression model and Analysis of Variance (ANOVA) for two groups was used to compare means of CO among biomass fuel, and mixed fuel users. Independent sample t-test of variables with concentration of CO was checked. The levels of CO data were compared with the WHO Air Quality Guideline (AQG) values. The device reported the level of CO in parts per million (ppm), and was converted to mg/m3 as follows: mg/m^3= (reported ppm value) *(MW)/STP values (20), where, MW=gram molecular weight of CO, 28.01, STP=Standard Temperature and Pressure values at 25^0c, 24.45.

RESULTS

The concentration of CO was monitored in 56 households, but due to poor quality measurement, 11 households were discarded. Among 55 households, 45 (81.8%) of biomass fuel user and 10 (18.2%) were mixed fuel user households. The type of fuel used for cooking was significantly associated at p-value <0.05 with only to monthly income of the household and house ownership, while the rest sociodemographic variables were not significantly associated with type of fuel used for cooking (Table 1).

The type of fuel used for cooking was significantly associated at p-value <0.05 with number of windows of the house, type of stoves used and time spent in cooking. But the rest variables were not significantly associated with type of fuel used for cooking (Table 2).

A 24 Hr. mean CO concentrations were presented in simple Boxplot figure indicated the median, the inter-quartile range (the middle 50% of the data), lower and upper quartiles, the upper 25% and lower 25% of the data. Hence, it' s clear that the middle 50% of scores were more spread out for the biomass fuel user group than for those who used mixed type of fuels because the box is much longer. Within each box, there is a thick horizontal line, which shows the median, in this case it was similar in both type of fuels. The biomass fuel users had a higher median than the mixed fuel users. The range of means was much wider for the biomass fuel users than the mixed fuel users (Figure 1).

The 24 hour measurmnet of mean concentration of CO in all monitored households were 14.26 mg/m^3 (SD=10.06) with 95% CI of Mean 11.54, 16.98. The magnitude of CO were different for different fuel sources, which was the larger in biomass fuel users accounted to 14.41mg/m^3 (SD=10.29) and followed by mixed type of fuel user, 13.55 mg/m^3 (SD=9.41). One way ANOVA was analysed between fuel types, and found to be not statistical significant resulted more or less similar mean concentration of carbon monoxide between both type of fuels used in households [$F(1, 53)=0.059$, $P=0.809$] (Table 3).

A 24-hour mean CO concentrations were presented in a graph showing a distribution of concentrations emitted from in different source of fuels (wood, charcoal and mixed) in the households (Figure 2).

The 24-hour mean CO concentrations were varied according to the number rooms and windows of the house; it was highest in the one room, one window and one door houses than the two or more rooms, windows and doors houses respectively. Those who used a separate kitchen for cooking were showed slightly lower concentration of CO than those who used inside the house. Open stoves and improved stove users had no significant difference in concentration of CO. Those who spent one hour in cooking indicated higher concentrations of CO than spending two hour or more hour in cooking. As to the level of house ventilation, adequately ventilated houses showed least concentrations of CO than moderately or poorly ventilated houses (Table 4).

DISCUSSION

The mean (SD) concentration of CO in Wolaita Sodo town households were 14.26 mg/m^3 (10.06). The magnitude of CO were different for different fuel sources, which was higher in biomass fuel users 14.41 mg/m^3 and followed by mixed fuel users, 13.55 mg/m^3.

According to the World Health Organization (WHO) Guidelines for Indoor Air Quality (IAQ) recommendation, CO for 24-hour mean concentration in houses should not exceed 7mg/m^3 (20, 21). WHO also suggests of CO for 8 hour exposure should not exceed above 10 mg/m^3 (20, 21). Our study result indicated that carbon monoxide was twice higher than the WHO IAQ guideline in the monitored houses. This is indicating that the study area used other CO emitting activities, such as tobacco smoke, incense and exhaust of motor vehicle from outside environment. The study households could be using charcoals as their alternate choice of fuel where electric fuel was not available, as charcoal is a known emitting sources of CO.

In Ethiopia (city of Addis Ababa, Bonga and Kebribeyah refugee camps), a study was undertaken to assess the potential of two types of improved cookstoves to reduce indoor air pollution, the 24-hour CO were 38.9 ppm (≈44.54 mg/m3) (14), which was significantly three times higher than the current study. The reason could be, in the previous studies of Bonga and

Kebribeyah study areas were refugee camps, the dominant cooking fuels could be biomass plus the difference in sample size. Similarly, the average 48 hour measurement of CO kitchen concentration in the charcoal and kerosene stove case were reported to 28.2 mg/m3 in a Clean Cook Stove Tests in Addis Ababa, Ethiopia (22), which was twice higher than the current study. Another study was conducted in one of the most common practice of the coffee ceremony in Ethiopia showed that particulate matter and carbon monoxide exposures for both preparers and participants were increases, and these increases exceeded the WHO exposure guidelines (23), because charcoal is the primary choice of fuel sources in coffee ceremony, in Ethiopia.

The CO concentration were compared with previous studies across the world, and the mean 48-h kitchen CO concentration in 60 homes of Michoacan, Mexico with the traditional fogon was 8.2 ppm (≈9.39 mg/m3) (17); in Palwal District of Haryana, India, a 24-hour personal CO concentrations were 5.27 ppm (≈6.03 mg/m3) (5), which was lower than the current study. The possible justification might be the personal exposure measurement is slightly lower than the indoor air measurement. Daily average CO concentrations collected in area near stove were 10.9 (10.5–11.3) ppm among households with traditional cookstoves in Southern Nepal in cookstove intervention trial study (24).

Our study had revealed a similar level of exposure to a study in Ghana, which was undertaken to assess the potential of two types of improved cookstoves to reduce indoor air pollution, the 24-hour CO concentration were measured to be12.3 ppm (≈14.08 mg/m3) (14).

The limitation of this study was that the measurement was a onetime measurement which was unable to consider seasonal pattern, the mixed use of fuels by the households causes difficulty to determine the level of carbon monoxide by type of fuels. Meanwhile, it was lacking linking between the level of concentration of carbon monoxide pollutant in a household and specific family health outcomes.

CONCLUSION

The concentration of CO exceeded the WHO AQG values CO concentrations in our study was slightly lower than other most previously conducted studies, but the overall concentration is unacceptable. Lower number of rooms, doors and windows of the house, biomass fuel, dominantly charcoal fuel users house, cooking inside the house and in poorly ventilated houses were determinants of CO concentration in the house. Therefore, clean fuel supply, use of improved stoves or electric stove, improve house design is encouraged. Clean energy supply to the community is can solve the root problem of household air pollution.

Ethical approval and consent to participate

Ethical clearance was obtained from Addis Ababa University, Institutional Review Board Office. Informed consent to participate in the study was obtained. For this, subject information sheet and informed consent letter was attached to each questionnaire. Participants were informed that participating is voluntarily and have no risk or harm. The right of the respondent to withdraw from the interview or not to participate was respected.

Consent for publication: Not applicable

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Competing interest: The authors declare that they have no competing interests.

Authors' Contributions

AA carried out protocol development, data collection, data management and analyses, and writing the manuscript. AK and AW were involved in protocol development, providing field work monitoring, and editing the manuscript. WT was involved in technical support. All authors read and approved the manuscript.

REFERENCES

1. Carlos Torres-Duque, Dario Maldonado, Rogelio Perez-Padilla, Majid Ezzati, Giovanni Viegi. Forum of International Respiratory Societies Report: Biomass Fuels and Respiratory Diseases; A Review of the Evidence. Proc Am Thorac Soc. 2008;5:577-90.
2. Chhabi Lal Ranabhat, Chun-Bae Kim, Chang-Soo Kim, Nilambar Jha, K.C Deepak, Connel FA. Consequence of indoor air pollution in rural area of Nepal: a simplified measurement approach. Frontiers in public health. 2015;3:5.
3. Dionisio KL, Stephen R.C.Howie, Francesca Dominici, Kimberly M. Fornace, John D. Spengler, Simon Donkor, et al. The exposure of infants and children to carbon monoxide

from biomass fuels in The Gambia: a measurement and modeling study. Journal of Exposure Science and Environmental Epidemiology. 2012;22:173-81.

4. Kalpana Balakrishnan, Padmavathi Ramaswamy, Sankar Sambandam, Gurusamy Thangavel, Santu Ghosh, Priscilla Johnson, et al. Air pollution from household solid fuel combustion in India: an overview of exposure and health related information to inform health research priorities. Global Health Action. 2011;4(5638).
5. Mukhopadhyay R, Sambandam S, Pillarisetti A, Jack D, Mukhopadhyay K, Balakrishnan K, et al. Cooking practices, air quality, and the acceptability of advanced cookstoves in Haryana, India: an exploratory study to inform large-scale interventions. Glob Health Action. 2012;5:1-13.
6. Clark ML, Reynolds SJ, Burch JB, Conway S, Bachand AM, Peel J. Indoor air pollution, cookstove quality, and housing characteristics in two Honduran communities. Environ Res. 2010 110(1):12-8.
7. Yamamoto S.S, V. R. Louis, A. Sié, Sauerborn R. Biomass smoke in Burkina Faso: what is the relationship between particulate matter, carbon monoxide, and kitchen characteristics? Environ Sci Pollut Res. 2014;21:2581-91.
8. Amanda Northcross, Zohir Chowdhury, John McCracken, Eduardo Canuz, Smith KR. Estimating personal PM2.5 exposures using CO measurements in Guatemalan households cooking with wood fuel. Journal of Environmental Monitoring. 2010;12:873-8.
9. Habtamu Sanbata, Araya Asfaw, Kumie A. Indoor air pollution in slum neighbourhoods of Addis Ababa, Ethiopia. Indoor Air Pollution (IAP) Updates from the WASHplus Project. Atmospheric Environment. 2014.

10. Bureau WzH. Wolaita zone health bureau annual report. In: Zone W, editor. Wolaita Sodo, Ethiopia: Wolaita zone Health Bureau; 2016.

11. Amha Admasie, Abera Kumie, Worku A. Association of Household Fuel Type, Kitchen Characteristics and House Structure with Child Size at Birth in Wolaita Sodo, Southern Ethiopia. The Open Public Health Journal. 2018;11:298-308.

12. Amha Admasie, Abera Kumie, Worku A. Children under Five from Houses of Unclean Fuel Sources and Poorly Ventilated Houses Have Higher Odds of Suffering from Acute Respiratory Infection in Wolaita-Sodo, Southern Ethiopia: A Case-Control Study. Journal of Environmental and Public Health. 2018;2018:9.

13. CSA. Recent Survey Releases: New towns population projection. Governmnet report. Addis Ababa, Ethiopia: Central Statistical Agency, 2018 31-Aug-2018. Report No.

14. David Pennise, Simone Brant, Seth Mahu Agbeve, Wilhemina Quaye, Firehiwot Mengesha, Wubshet Tadele, et al. Indoor air quality impacts of an improved wood stove in Ghana and an ethanol stove in Ethiopia. Energy for Sustainable Development. 2009;13:71-6.

15. California-Berkeley Uo. Standard Operating Procedure: HOBO Carbon Monoxide Logger. (Collection, Downloading, and Storage of Data). University of California-Berkeley: Indoor Air Pollution Team and Center for Entrepreneurship in International Health and Development (CEIHD) School of Public Health, University of California-Berkeley; 2005.

16. Kalpana Balakrishnan, Sankar Sambandam, Padmavathi Ramaswamy, Sumi Mehta, Smith K. Indoor air pollution associated with household fuel use in India: Exposure assessment for respirable particulates associated with household fuel use in rural districts of Andhra Pradesh, India. Journal of Exposure Analysis and Environmental Epidemiology. 2004;14:S14-S25.

17. Cynthia Armendáriz Arnez, Edwards Rufus D, Johnson Michael, Zuk Miriam, Rojas Leonora, Jiménez Rodolfo Díaz, et al. Reduction in personal exposures to particulate matter and carbon monoxide as a result of the installation of a Patsari improved cook stove in Michoacan Mexico. Indoor air. 2008;18(2):93-105.

18. Edwards RD, Liu Y, He G, Yin Z, Sinton J, Peabody J, et al. Household CO and PM measured as part of a review of China's National Improved Stove Program. Indoor Air. 2007;17:189-203.

19. Berkeley UoC. Standard Operating Procedure Installing Indoor Air Pollution Instruments in a Home. University of California Berkeley: Indoor Air Pollution Team and Center for Entrepreneurship in International Health and Development (CEIHD) School of public health, University of California Berkeley; 2005.

20. WHO. WHO guidelines for indoor air quality: selected pollutants. Bonn: World Health Organization: WHO, 2010.

21. WHO. WHO guidelines for indoor air quality: household fuel combustion. Geneva, Switzerland: WHO, 2014.

22. Association G. Indoor Air Pollution Monitoring Summary For Gaia Association-Ethiopia's Clean Cook Stove Tests in Addis Ababa, Ethiopia. 2007.

23. Chris Keil, Hailu Kassa, Alexander Brown, Abera Kumie, Tefera W. Inhalation Exposures to ParticulateMatter and Carbon Monoxide during Ethiopian Coffee Ceremonies in Addis Ababa: A Pilot Study. Journal of Environmental and Public Health. 2010;2010:8.

24. Chen C, Zeger S, Breysse P, Katz J, Checkley W, Curriero FC, et al. Estimating Indoor PM(2.5) and CO Concentrations in Households in Southern Nepal: The Nepal Cookstove Intervention Trials. PLoS ONE. 2016;11(7):e0157984.

ANNEX-II: DATA COLLECTION TOOLS

ENGLISH VERSION

General information

001	House No. (code)	________/______/_______
002	Kebele	
003	Sub Kebele (Sefer)	
004	Household benchmark	
005	Name of household Head	
006	Name of household respondent	

PART 1: SOCIODEMOGRAPHIC INFORMATION

SN	Questions	Response
101	Age of the mother (Completed years)	-------------------------
102	What is the respondent relationship with the child?	1. Mother 2. Care taker
103	Marital status	1. Married 2. Single 3. Divorced/Separated 4. Widowed
104	Educational status of the mother	1. Unable to read and write 2. Able to read and write 3. Primary education (Grade 1-6) 4. Secondary (Grade 7-12) 5. Diploma, degree and above
105	Educational status of the father	1. Unable to read and write 2. Able to read and write 3. Primary education (Grade 1-6)

		4. Secondary (Grade 7-12) 5. Diploma, degree and above
106	Occupational status of the mother	1. Employee (GO, NGO) 2. Self-employee (private) 3. Farmer (Smallholder) 4. Petty Trade 5. Daily laborer 6. Unemployed 7. House wife 99. Other (Specify)----------
107	Occupational status of the father	1. Employee (GO, NGO) 2. Self-employee (private) 3. Farmer (Smallholder) 4. Petty Trade 5. Daily laborer 6. Unemployed 99. Other (Specify)----------
108	Ethnicity of the house head	1. Wolaita 2. Amhara 3. Tigre 99. Other (specify)------
109	Religion of the house head	1. Orthodox 2. Protestant 3. Catholic 4. Islam 99. Other (specify)------
110	How many people live in your home?	T____ M ___ F____
111	Monthly Income for the household	1. <1000 ETB 2. 1000-3000 ETB 3. 3000-5000 ETB 4. >5000 ETB

112	House ownership	1. Own 2. Rent
113	What is the source of your drinking water? (Multiple answers may apply)	1. Tap water within yard 2. Piped to neighbor 3. Public tap/standpipe 4. Private protected well 5. Private unprotected well 6. Spring water 7. River water 99. Other (Specify)________
114	Time to obtain drinking water (round trip	1. Water on premises 2. Less than 30 minutes 3. 30 minutes or longer 4. Don't know/missing
115	What type of latrine do you have?	1. No latrine 2. Pit latrine without super structure 3. Pit latrine with slab & super structure 4. VIP latrine 5. Flush/pour flush to septic tank/pit latrine 99. Other (specify)____________

PART 2. PROPERTY TYPES AND QUANTITY

	Property types and amount	Yes		No (0)
		Yes (1)	If yes, how many?	
201	Electricity			

202	Table			
203	Chair			
204	A kerosene lamp/pressure lamp/Solar power			
205	A bed with cotton/ sponge/spring mattress			
206	Mobile telephone			
207	Fixed or wireless telephone			
208	Radio			
209	Television			
210	Watch/clock			
211	An electric stove			
212	Refrigerator			
213	Cars (including three tire cars)			
214	Motorbike			
215	Bicycle			
216	Animal driven cart			
217	Agricultural land (in hectare, *Timad*)			
218	Oxen			
219	Cows			
220	Donkey			
221	Horse/mule			
222	Sheep			
223	Goats			

224	Poultry			
225	Bee hive			
226	Saving accounts			

PART 3. CHILD PROFILE

SN	Questions	Response	Skip
301	How many children aged 0-59 months live in your home?	_______children	
302	Sex of a child (Randomly selected) Name___________________	1. Male 2. Female	
303	Date of child birth (DDMMYY)	------/------/-----------	
304	Age of a child (convert in months) (Check your calendar)	-----------------	
305	Child size at birth (recall or check either ways)	1. Very small 2. Small 3. Average 4. Large 5. Very large	
306	Was your child born at term?	1. Yes 2. No 88. Don't know	
307	Birth order in number	_______________	
308	Had you ever a follow up for antenatal care?	Yes No	
309	Where did you born your child?	1. At home 2. With traditional birth attendant 3. Government Health facilities	

		4. Private Health facilities 99. Other (Specify)___	
310	If you delivered your child in health facilities, how did you deliver?	1. Normal delivery 2. Caesarian section 3. Instrumental delivery 88. Other (Specify)-----	
311	The interval after the previous birth (Birth spacing)	1. First birth 2. ≤2 years 3. >2 years	
312	Does he/she attend or regular school, day care, nursery school?	1. Yes 2. No	
313	How many people share his/her bedroom?	1. Own room 2. 1 person 3. 2 persons 4. 3 or above	
314	Did you breast fed your child?	1. Yes 2. No 3. I don't remember	
315	If yes to Q. 314, at what time you started breast fed?	1. Within an hour 2. Within 24 hours 3. After 24 hours 4. I don't remember	
316	Currently, are you breast fed your child?	1. Yes 2. No	
317	When does the child start complimentary foods?	_______ months	
318	Immunization status (Check the immunization card)	1. Yes 2. Partially 3. No	

319	Does the child wash his hands with soap at most important times? (After defecation, before touching foods and before eating)	1. Yes 2. No	
320	Does the mother or caregiver wash her hands with soap at most important times? (After defecation, after cleaning a child who has defecated, before touching or preparing food, Before Eating, before feeding a child)	1. Yes 2. No	
321	Has (NAME) had an illness with cough at any time in the last two weeks?	1. Yes 2. No 3. I don't know	
322	When (NAME) had an illness with a cough, did he/she have trouble breathing or breath faster than usual, with short, fast breaths?"	1. Yes 2. No	
323	Did you seek advice or treatment for the cough/fast breathing?	1. Yes 2. No	

PART 4. CHARACTERIZATION OF HOUSEHOLD

S. N	Questions	Response
401	When the house is constructed? (in years)	___________
402	How many rooms (excluding bathrooms) in the house?	__________
403	How many doors are there in the house? (able to open)	__________
404	How many windows are there in the house? (able to open)	__________
405	Are there any openings (gap between wall and roof) in the house?	1. Yes 2. No
406	Floor material of the house	1. Earthen/Mud 2. Plastic cover 3. Cement/Tiles 4. Others (Specify)------
407	Wall material of the house	1. Grass/wood/bamboo 2. Mud

		3. Blocks/Bricks/stones 4. Others (Specify)------
408	Roof material of the house	1. Thatch roof 2. CIS/ metal sheet 3. Concrete/Tiles 4. Others (Specify)-----

PART 5. CHARACTERIZATION OF THE KITCHEN

S. N	Questions	Response	Skip pattern
501	Arrangements of kitchen related to the living room (See the attached kitchen arrangements)	1. Indoor kitchen without partition 2. Indoor kitchen with partition 3. Separate kitchen outside house 4. Open air kitchen outside house	→ 508
502	Are there any other openings in the kitchen?	1. Yes 2. No	
503	Does the kitchen have a chimney?	1. Yes 2. No	
504	Floor material of the kitchen	1. Earthen/Mud 2. Plastic cover 3. Cement/Tiles 4. Others (Specify)-----------	
505	Wall material of the kitchen	1. Grass/leaves/Wood/Bamboo 2. Mud 3. CIS/metal sheet 4. Blocks/Bricks/stones 5. Others (Specify)----------	
506	Roofing material of the kitchen	1. Thatch roof 2. Plastic 3. Corrugated Iron sheet 4. Concrete/Tiles	

		5. Others (Specify)---------	
507	Opening of windows during the time of cooking	1. Yes 2. No	
508	Is the stove located under any shed, roof or canopy?	1. Yes 2. No	

PART 6. TYPE OF FUEL USE AND COOKING STOVE

SN	Questions	Response	Skip
601	What type of fuel does your household mainly/primarily used for cooking? (Probe for types)	1. Electricity 2. Biogas/LPG stove 3. Kerosene 4. Charcoal 5. Wood, straw, crop residue, cow dung, grass, shrubs 99. Other (specify)____________	
602	What type of fuel does your household mainly use for lighting? (Probe for types)	1. Electricity 2. Solar energy 3. Biogas/ LPG stove 4. Kerosene 5. Wood, straw, crop residue, cow dung, grass, shrubs 99. Other (specify)____________	
603	How do you get access to fuel sources	1. Purchased 2. Collected 3. Both 4. Other (Specify)_______________	
604	What type of cooking stove is usually used in your house?	1. Open fire/stove without chimney/hood 2. Open fire/stove with chimney/hood 3. Closed /improved/ stove with chimney 4. Electrical stove	

		99. Other(specify)____________	
605	Where is cooking usually done? (Practically)	1. In a room used for living/sleeping 2. In a separate room used as kitchen 3. In a separate building used as kitchen 4. Outdoors	
606	In what season do you consume more fuel?	1. Dry season 2. Wet season	

PART 7. HOME PRACTICE

SN	Questions	Response	Skip to
701	How often you ignite to cook in a day?	1. Once 2. Twice 3. Three and above times	
702	What is the average time spent per day in cooking? (in Hours)	____________________hours	
703	Do you cook injera in your house?	1. Yes 2. No	
704	How often times you cook injera in a week?	1. Once 2. Twice 3. Three and above times	
705	Do you cook food for commercial purpose?	1. Yes 2. No	
706	Is a child usually present in the kitchen during cooking?	1. Yes 2. No	
707	Is there a habit of carrying a child by a mother while cooking?	1. Always 2. Sometimes 3. Never	
708	How often times clean the kitchen?	1. Weekly	

		2. Twice a week 3. More than twice a week 4. Daily	
709	Do you smoke incense, mosquito or fly coils frequently?	1. Yes 2. No	
710	Is there any family member who smokes cigarette?	1. Yes 2. No	
711	If yes to Qn. 710, how often does anyone smoke inside your home?	1. Daily 2. Weekly 3. Monthly 4. Less than monthly 88. Don't Know	
712	If yes to Qn. 710, how long does anyone who smokes Cigarette? (in years)	______________years	
713	If yes to Qn. 710, how many numbers of Cigarettes smoked per day in average?	_____________cigarettes	

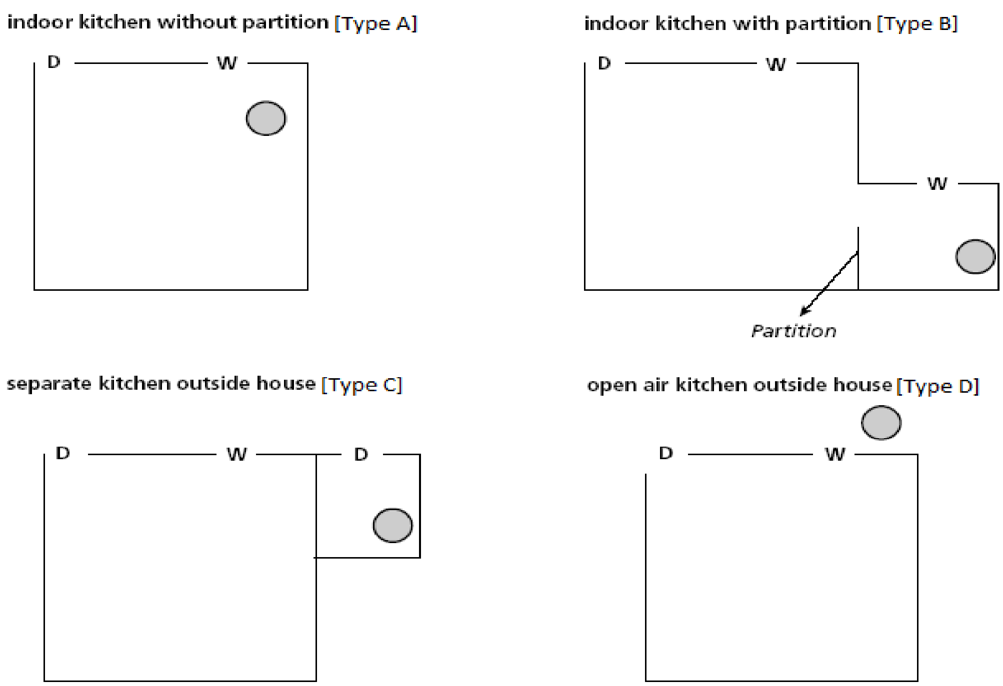
PART 8: OBSERVATIONAL CHECK LIST DURING THE VISIT TIME

SN	Observation Variables	Yes	No	Doesn't Apply
	House			
801	Does the house have window?	1	2	88
802	Is the house's window opened during the visit?	1	2	88
803	Are there any other openings in the house for natural ventilation?	1	2	88
804	Are openings sufficient for house ventilation	1	2	88
805	Is there a functional chimney in the house?	1	2	88
806	Is the house roof and wall look black due to smoke?	1	2	88
	Kitchen			
807	Does the kitchen have window?	1	2	88
808	Is the kitchen's window opened during the visit?	1	2	88

809	Are there any other openings in the kitchen for natural ventilation?	1	2	88
810	Is there window for kitchen during the visit?	1	2	88
811	Is there a functional chimney in the kitchen?	1	2	88
812	Is the kitchen roof and wall look black due to smoke?	1	2	88
813	Is the kitchen far enough from the main house? (For separate kitchen and open stove)	1	2	88
814	Does the kitchen serve for other purpose other than cooking?	1	2	88
815	Is the kitchen clean?	1	2	88
	Activity pattern			
816	What type of fuel source used during the visit?	1. Electricity 2. Biogas/LPG stove 3. Kerosene 4. Charcoal 5. Wood, straw, crop residue, cow dung, grass, shrub 6. Other (specify)____________		
817	What type of stove used during the visit?	1. Open fire/stove without chimney/hood 2. Open fire/stove with chimney/hood 3. Closed /improved/ stove with chimney 4. Electrical stove 99. Other(specify)____________		
818	What type of meal cooking during the visit?	1. Nothing was cooking 2. Baking injera 3. Cooking Wat 4. Baking bread 5. Boiling water 99. Other(specify)____________		
819	How many children are there during the cooking time?	1. None 3. 1		

		4. 2 5. ≥3
820	Does a cook carry child during cooking?	1. Yes 2. No
821	Please rate the ventilation of the kitchen	1. Poor (only one door) 2. Moderate (one door and one window) 3. Good (more than one door and one window)

Thank you for your cooperation!!



Type of kitchens and arrangement diagram

HOUSEHOLD AIR POLLUTION MONITORING SAMPLING FORM

Kebele_________ HHID: _________ HH owner name: _______________Phone N______________

1. <u>The UCB particle monitor (UCB-PM)</u>

Pre-Field Operations (In Lab)

A. UCB-PM zero baseline calibrations				
UCB-PM ID	Date (DD-MM-YYYY)	Zero Start Time (hh:mm)	Zero End Time (hh:mm)	Fan Check
— — — —			(+ 5 minutes)	[] Off [] *On*

In-Field Operations – KITCHEN AREA Monitors

B. UCB-PM KITCHEN (In Field)						
UCB-PM ID	Start Date (DD-MM-YYYY)	Start Time (hh:mm)	Fan Status Check at		End Date (DD-MM-YYYY)	End Time (hh:mm)
			12hr	24hr		
— — — —			[] Off [] *On*	[] Off [] *On*		
C. UCB-PM Downloaded file name: ________________						

2. **<u>CO Data Logger</u>**

D. CO data logger zero baseline calibrations				
CO data logger ID	Date (DD-MM-YYYY)	Zero Start Time (hh:mm)	Zero End Time (hh:mm)	Fan Check
— — — —			(+ 5 minutes)	[] Off [] *On*

E. CO data logger (In Field)				
CO Data logger ID	Start Date (DD-MM-YYYY)	Start Time (hh:mm)	End Date (DD-MM-YYYY)	End Time (hh:mm)
— — — —				
F. CO Downloaded file name: ________________				
Notes and Errors – KITCHEN Area Monitor Placement				
General notes and comments:				

የአማርኛ መጠይቅ

በወላይታ ሶዶ ከተማ ውስጥ በማገዶ ጭስ ምክንያት የሚከሰት የቤት ውስጥ የአየር ብክለት መጠንና በህፃናት ላይ ስለሚያስከትለው አጣዳፊ የመተንፈሻ አካላት ችግሮችና ምልክቶች የዳሰሳ ጥናት

ጠቅላላ መረጃ

001	የቤት ቁጥር (መለያ)	___________/___________/___________
001	ቀበሌ	
003	ሰፈር (ልዩ መጠሪያ)	
004	የቤቱ ልዩ ምልክት	
005	የቤቱ አባውራ ስም	
006	ቃለ መጠይቅ የተደረገለት ሰው ስም	

ክፍል 1: ግለሰባዊ መረጃ/ Sociodemographic status

ተ.ቁ	ጥያቄ	ምላሽ
101	የእናት ወይም የአሳዳጊ እድሜ ስንት ነው (በዓመት)	-------------------------------
102	ተጠያቂዋ ከልጁ ጋር ያላት ዝምድና?	1. እናት 2. አሳዳጊ
103	የጋብቻ ሁኔታ	1. ያገባች 2. ያላገባች 3. የፈታች/የተለያየች 4. ባል የሞተባት
104	የእናት የትምህርት ደረጃ	1. ማንበብና መፃፍ የማትችል 2. ማንበብና መፃፍ የምትችል 3. የመጀመሪያ ደረጃ ትምህርት 4. የሁለተኛ ደረጃ ትምህርት 5. ዲፕሎማ፤ ዲግሪና ከዚያ በላይ
105	የአባት የትምህርት ደረጃ	1. ማንበብና መፃፍ የሚችል 2. ማንበብና መፃፍ የማይችል 3. የመጀመሪያ ደረጃ ትምህርት

		4. የሁለተኛ ደረጃ ትምህርት 5. ዲፕሎማ፣ ዲግሪና ከዚያ በላይ		
106	የእናት የስራ ሁኔታ	1. ተቀጣሪ (መንግስታዊና መንግስታዊ ያልሆነ) 2. የግል ተቀጣሪ 3. የግብርና የሚተዳደሩ 4. የንግድ ስራ 5. የቀን ሰራተኛ 6. መደበኛ ሥራ የሌላት 7. የቤት እመቤት 99. ሌላ (ይገለፅ)----------		
107	የአባት የስራ ሁኔታ	1. ተቀጣሪ (መንግስታዊና መንግስታዊ ያልሆነ) 2. የግል ተቀጣሪ 3. የግብርና የሚተዳደሩ 4. የንግድ ስራ 5. የቀን ሰራተኛ 6. መደበኛ ሥራ የሌለው (የቤት አባውራ) 99. ሌላ (ይገለፅ)----------		
108	ብሄር (የቤቱ አባውራ ብሄር)	1. ወላይታ 2. አማራ 3. ትግሬ 99. ሌላ (ይገለፅ)----------		
109	ሃይማኖት (የቤቱ አባውራ የሚከተለው ሃይማኖት)	5. ኦርቶዶክስ 6. ፕሮቴስታንት 7. ካቶሊክ 8. እስልምና 99. ሌላ (ይገለፅ)----------		
110	በቤት ውስጥ ስንት ቤተሰብ ይኖራል?	ጠቅላላ_____	ወንድ ____	ሴት____ _

111	ወርሃዊ የገቢ መጠን	1. <1000 ብር 2. 1000-3000 ብር 3. 3000-5000 ብር 4. >5000 ብር
112	አሁን የምትኖሩበት ቤት የማን ነው?	1. የራሳችን 2. የኪራይ
113	የመጠጥ ውሃ አቅርቦት የምታገኙት የት ነው? (ከአንድ በላይ መልስ መመለስ ይቻላል)	1. ከግቢ ውስጥ የሚገኝ የውሃ ቧንቧ 2. ከጎረቤት የሚገኝ የውሃ ቧንቧ 3. ከቦኖ ውሃ የሚገኝ 4. ከግል የተጠበቀ የውሃ ጉድጓድ 5. ከግል ያልተጠበቀ የውሃ ጉድጓድ 6. የምንጭ ውሃ 7. የወንዝ ውሃ 99. ሌላ (ይገለጽ)--------------------
114	የመጠጥ ውሃ ለማግኘት (ቀድቶ) ለመመለስ ስንት ደቂቃ ይወስድባችኋል?	1. ውሃ ከግቢ ውስጥ አለን 2. ከ 30 ደቂቃ በታች 3. 30 ደቂቃና ከዚያ በላይ 88. አላውቅም
115	መፀዳጃ ቤታችሁ ምን ዓይነት ነው?	1. መፀዳጃ ቤት የለንም 2. ጣሪያ የሌለው ሽንት ቤት 3. 3. ጣሪያና ወለል ያለው ሽንት ቤት 4. የተሻሻለና ሽታ አልባ ሽንት ቤት 5. በውሃ በመጨመር የሚሰራ ሽንት ቤት 6. ሌላ ይገለጽ--------------

ክፍል 2. የሃብት ዓይነትና መጠን መረጃ

ተ.ቁ	የንብረት ዓይነትና መጠን	አለን (1)	ካለ፤ ስንት?	የለንም (0)
201	የኤሌክትሪክ መስመር/Electricity			
202	ጠረንጴዛ/Table			
203	ወንበር/Chair			
204	ኩራዝ/ማሾ መብራት/ሶላር/A kerosene lamp/pressure lamp/Solar			
205	ባለ ጥጥ/ስፖንጅ ፍራሽ አልጋ/A bed with cotton/ sponge/spring mattress			
206	ሞባይል ስልክ/Mobile telephone			
207	መደበኛ ስልክ/ Fixed or wireless telephone			
208	ሬዲዮ/Radio			
209	ቴሌቪዥን/Television			
210	የግድግዳ ሰዓት/Watch/clock			
211	የኤሌክትሪክ ምድጃ/An electric stove			
212	ፍሪጅ/Refrigerator			
213	መኪናዎች/ባጃጅ/Cars (including three tire cars)			
214	ሞተር ሳይክል/Motor bike			
215	ብስክሌት/Bicycle			
216	በእንስሳት የሚጎተት ጋሪ/Animal driven cart			
217	የእርሻ መሬት/Agricultural land (in hectare, Timad)			
218	በሬዎች /Oxen			
219	ላሞች/Cows			
220	አህያዎች/Donkeys			
221	ፈረሶች/በቅሎዎች/ Horses/mules			
222	በጎች/Sheep			
223	ፍየሎች/Goats			
224	ዶሮዎች/poultry			
225	የንብ ቀፎዎች/Bees Hives			

226	የባንክ ደብተር/Saving accounts			

ክፍል 3: የህፃኑ መረጃ /Child profile

ተ.ቁ	ጥያቄዎች	ምላሽ	ወደ --ሂድ
301	በቤት ውስጥ በህይዎት ያሉ እድሜአቸው ከ 0-59 ወራት የሆናቸው ህጻናት ስንት ናቸው?	________ህጻናት	
302	የህጻኑ ፆታ (በእጣ የተመረጠው) የህጻኑ ስም:____________________	1. ወንድ 2. ሴት	
303	ህጻኑ የተወለደበት ዕለት (ቀን) መቼ ነው? (ቀን/ወር/ዓ.ም)	-----/--------/----------	
304	የህጻኑ እድሜ (በወራት ቀይረህ አስቀምጥ)	------------------------	
305	ህጻኑ ሲወለድ ክብደቱ/መጠኑ ምን ያክል ነበር?	1. በጣም ትንሽ 2. ትንሽ 3. መካከለኛ 4. ትልቅ 5. በጣም ትልቅ	
306	ህፃኑ ሲወለድ ዘጠኝ ወሩን ጨርሶ ነበር?	1. አዎ 2. የለም 88. አላውቅም	
307	ህፃኑ ስንተኛ ልጅ ነው?	---------------	
308	የቅድመ ወሊድ ጤና ክትትል አድርገው ያውቃሉ?	1. አዎ 2. የለም	
309	ልጅዎን የት ነዉ የወለዱት?	1. ቤት ያለማንም አዋላጅ 2. ቤት በባህላዊ አዋላጅ 3. ከመንግስት ጤና ተቋማት 4. ከግል ጤና ተቋማት 99. ሌላ ካለ ይገለፅ ________	
310	ጤና ተቋም ከወለዱ እንዴት ነው የወለዱት	1. በማህፀን ያለምንም እገዛ 2. በቀዶ ጥገና (በኦፕሬሽን) 3. በማህፀን በመሳሪያ በታገዝ 99. ሌላ ካለ -------------	

311	ህፃኑ ከእርሱ በፊት ከተወለደው ህጻን በስንት ዓመት ያንሳል?	1. የመጀመሪያ ልጅ 2. ≤2 ዓመታት 3. >2 ዓመታት	
312	ህፃኑ መዋዕለ ህፃናት ወይም ማቆያ ቤት ይውላል?	1. አዎ 2. የለም	
313	የህፃኑን ምኝታ ክፍል የሚጋሩት ስንት ሰዎች ናቸው?	1. ብቻውን 2. 1 ሰው ብቻ 3. 2 ሰዎች ብቻ 4. 3 እና ከዚያ በላይ	
314	ልጅዎን ጡት አጥብተሽዋል/ሻታል?	1. አዎ 2. የለም 3. አላስታውስም	
315	ጥያቄ 314 አዎ ከሆነ፤ እንደ ተወለደ በምን ያህል ስአት ውስጥ ማጥባት ጀመሩ?	1. ከአንድ ስአት በማይበልጥ ጊዜ ውስጥ 2. በሀያ አራት ስአት ውስጥ 3. ከሀያ አራት ስአት በላይ 4. ማስተዋስ/ማወቅ አልቻሉም	
316	ልጅሽን ዛሬ ጡት እያጠባሽው ነው?	1. አዎ 2. የለም	
317	ለመጀመሪያ ጊዜ ለህፃኑ ከጡት ወተት በተጨማሪ ሌላ ተጨማሪ ምግብ ያስጀመሩት በስንት ወር ነበር?	________ ወር	
318	ህፃኑ በዕድሜው የሚገባውን ክትባት አግኝቷል? (የክትባት ካርዱን ተመልከት)	1. አዎ 2. በከፊል 3. የለም	
319	ህፃኑ ወሳኝ ሰዓት በሚባሉት ጊዜያት እጁን በውሃና በሳሙና ታጠቢዋለሽ? (ከተፀዳዳ በኋላ፤ ምግብን ከመንካቱ በፊት፤ ከመመገብ በፊት)	1. አዎ 2. የለም	

320	እርስዎ ወሳኝ ሰዓት በሚባሉት ጊዜያት እጆዎትን በውሃና በሳሙና የመታጠብ ልምድ አለዎት? (ከተፀዳዱ በኋላ፣ ህጻን ካፀዳዱ በኋላ፣ ምግብን ከማዘጋጀትት በፊት፣ ከመመገብ በፊት፣ ህጻን ከመመገብ በፊት)	1. አዎ 2. የለም	
321	ህፃኑ በባለፉት ሁለት ሳምንታት ውስጥ በአንዱ ቀን ሳል አስሎት (ሳል አሞት) ነበር?	1. አዎ 2. የለም 3. አላውቅም	
322	አዎ ካሉ፤- ሳል ማሳሉን ተከትሎ፤ህፃኑ ለመተንፈስ ተቸግሮ ነበር ወይም አተነፋፈሱ ከተለመደው ስርዓት ፈጣን፤አጭር፤ቁርጥ ቁርጥ የሚል ነበር?	1. አዎ 2. አይልም	
323	ለሳሉም ሆነ ለአተነፋፈሱ ችግር ምክር ወይም የህክምና እርዳታ አግኝተዋል?	1. አዎ 2. የለም	

ክፍል 4. *ሥለ ቤቱ ሁኔታ/ገጽታ*/House structure

ተ.ቁ	ጥያቄዎች	ምላሽ
401	ቤቱ የተሰራው/የተገነባው መቼ ነው? (በዓመት ይገለፅ)	___________
402	የመታጠቢያ ክፍሎችን ሳይጨምር ቤቱ ስንት ክፍሎች አሉት?	___________
403	ቤቱ ስንት በሮች አሉት? (ሊከፈቱ የሚችሉትን ብቻ)	___________
404	ቤቱ ስንት መስኮቶች አሉት? (ሊከፈቱ የሚችሉትን ብቻ)	___________
405	ቤቱ በግድግዳውና በጣሪያው መካከል ክፍተት ወይም ሌላ ቀዳዳ አለው?	1. አዎ 2. የለም
406	የቤቱ ወለል የተሰራበት ቁሳቁስ ምንድን ነው?	1. አፈር/ጭቃ 2. ፕላስቲክ 3. ሲሚንቶ/ሸክላ 4. ሌላ (ይገለፅ)------
407	የቤቱ ግድግዳ የተሰራበት ቁሳቁስ ምንድን ነው?	1. ሳር/እንጨት/ሸምበቆ 2. ጭቃ 3. ብሎኬት/ጡብ/ድንጋይ

		99. ሌላ (ይገለፅ)------
408	የቤቱ ጣሪያ የተሰራበት ቁሳቁስ ምንድን ነው?	1. ሳር 2. ቆርቆሮ/ብረት 3. ሲሚንቶ/ሸክላ 99. ሌላ (ይገለፅ)-----

ክፍል 5. ስለ ኩሽና ሁኔታና ገጽታ

ተ.ቁ	ጥያቄዎች	ምላሽ	ወደ -- ሂድ
501	የኩሽና ቤቱ አቀማመጥ ከመኖሪያ ቤቱ አንጻር ምን ይመስላል? (የኩሽና ቤት አቀማመጥ መግለጫ ተመልከት)	1. ከመኖሪያ ቤቱ ጋር ያለ አካፋይ 2. ከመኖሪያ ቤቱ ጋር በአካፋይ 3. ከመኖሪያ ቤቱ ተነጥሎ ለብቻ የተሰራ 4. ከመኖሪያ ቤቱ ውጭ ሜዳ ላይ →	508
502	የኩሽና ቤቱ ለአየር መግቢያ የሚሆን ቀዳዳ አለው?	1. አዎ 2. የለም	
503	የኩሽና ቤቱ የጭስ ማውጫ አለው?	1. አዎ 2. የለም	
504	የኩሽና ቤቱ ወለል የተሰራበት ቁሳቁስ	1. አፈር/ጭቃ 2. ፕላስቲክ 3. ሲሚንቶ/ሸክላ 99. ሌላ (ይገለፅ)------	
505	የኩሽና ቤቱ ግድግዳ የተሰራበት ቁሳቁስ	1. ሳር/ቅጠል/እንጨት/ሸምበቆ 2. ጭቃ 3. ቆርቆሮ/ብረት 4. ብሎኬት/ጡብ/ድንጋይ 99. ሌሎች (ይገለጽ)----------	
506	የኩሽና ቤቱ ጣሪያ የተሰራበት ቁሳቁስ	1. ሳር 2. ፕላስቲክ 3. ቆርቆሮ	

		4. ሲሚንቶ/ሸክላ 99. ሌሎች (ይገለጽ)----------	
507	ምግብ በማብሰያ ጊዜ መስኮቶች ይከፈታሉ?	1. አዎ 2. አይከፈቱም	
508	የማብሰያው ምድጃ የሚገኝበት ቦታ መጠለያ ወይም ዳስ ወይም ጥላ አለው?	1. አዎ 2. የለም	

ክፍል 6. የሃይል ምንጭ ዓይነትና የማብሰያ ምድጃ /TYPE OF FUEL USE AND COOKING STOVE

ተ.ቁ.	ጥያቄዎች	ምላሽ	ወደ --ሂድ
601	በቤትዎ ውስጥ ለምግብ ማብሰያነት የምትጠቀሙት በዋናነት ምን ዓይነት የሃይል ምንጭ ነው? (ዓይነቶችን ዘርዝር)	1. ኤሌክትሪክ 3. ሲሊንድር ጋዝ ምድጃ/ ባዮጋዝ 4. ኪሮሲን/ጋዝ 5. ክሰል 6. እንጨት, ገለባ, የእፅዋት ተዋጽኦ, ኩበት, ሳር, ቁጥቋጦ 99. ሌሎች (ይገለጽ)----------	
602	በቤትዎ ውስጥ ለመብራት አገልግሎት የምትጠቀሙት በዋናነት ምን ዓይነት የሃይል ምንጭ ነው? (ዓይነቶችን ዘርዝር)	1. ኤሌክትሪክ 2. የፀሃይ ሃይል 3. ባዮጋዝ/ሲሊንድር ጋዝ ምድጃ 4. ኪሮሲን ጋዝ/ኩራዝ 5. እንጨት, ገለባ, የእፅዋት ተዋጽኦ, ኩበት, ሳር, ቁጥቋጦ 99. ሌሎች (ይገለጽ)----------	
603	በቤትዎ ውስጥ ለምግብ ማብሰያነትም ሆነ ለመብራት የምትጠቀሙትን የሃይል ምንጭ የት ነው የምታገኙት?	5. በመግዛት 6. በራሳችን የተሰበሰበ/የተለቀመ 7. በመሰብሰብም በመግዛትም 99. ሌሎች (ይገለጽ)----------	

604	በአብዛኛው ለምግብ ማብሰያነት የምትጠቀሙበት ምን ዓይነት ምድጃ ነው? (የምድጃ ዓይነቶችን መግለጫ ተመልከት)	1. ክፍት ምድጃ ጭስ ማውጫ የሌለው 2. ክፍት ምድጃ ጭስ ማውጫ ያለው 3. ዝግ ምድጃ(የተሻሻለ) ጭስ ማውጫ ያለው 4. የኤሌክትሪክ ምድጃ/ምጣድ 99. ሌሎች (ይገለጽ)----------	
605	በአብዛኛው ጊዜ ምግብ የምታበስሉት የት ነው?	1. ከመኖሪያ ቤት ውስጥ 2. ከመኖሪያ ቤት ውስጥ ለኩሽና በተከፈለ ቦታ 3. ለኩሽና ተብሎ ተለይቶ በተሰራ ቤት ውስጥ 4. ውጭ ላይ (ሜዳ ላይ)	
606	በምን ዓይነት ወቅት ነው ብዙ የሃይል ምንጭ የምትጠቀሙት?	1. በበጋ ወቅት 2. በክረምት ወቅት	

ክፍል 7. የቤት ውስጥ ልምዶች/HOME PRACTICE

ተ.ቁ.	ጥያቄዎች	ምላሽ	ወደ -ሂድ
701	በቀን ውስጥ ስንት ግዜ ምድጃ ትለኩሳላችሁ/ትጠቀማላችሁ?	1. አንድ ግዜ 2. ሁለት ግዜ 3. ከሶስትና ከዚያም በላይ	
702	በቀን ውስጥ ለምን ያክል ግዜ ምግብ በማብሰል ታሳልፋላችሁ?	------------------------ሰዓታት	
703	በቤት ውስጥ እንጀራ ትጋግራላችሁ?	1. አዎ 2. የለም	
704	በሳምንት ውስጥ ለስንት ግዜ እንጀራ ትጋግራላችሁ?	1. አንድ ግዜ 2. ሁለት ግዜ 3. ከሶስትና ከዚያም በላይ	
705	ለንግድ/ለሽያጭ/ አገልግሎት የሚውል ምግብ ታበስላላችሁ?	1. አዎ 2. የለም	
706	ምግብ በምታበስሉበት ወቅት ህጻናት በአብዛኛውን ግዜ ከእናንተ አካባቢ ይገኛሉ?	1. አዎ 2. የለም	

707	ምግብ በምታበስሉበት ግዜ ህጻናትን በጀርባ የማዘል ልምድ አለዎት?	1. ሁሌም 2. አልፎ አልፎ 3. በፍጹም	
708	ኩሽና ቤትዎን በምን ያክል ግዜ ነው የሚያጸዱት?	1. በሳምንት አንድ ግዜ 2. በሳምንት ሁለት ግዜ 3. በሳምንት ከሁለት ግዜ በላይ 4. በየቀኑ	
709	በቤትዎ ውስጥ ሰንደል፤ ዕጣን እና ለትንኝና ለዝንብ ማባረሪያ ጭስ በተደጋጋሚ ትጠቀማላችሁ?	1. አዎ 2. የለም	
710	ከቤተሰቡ መካከል ሲጋራ የሚያጨስ ሰው አለ?	1. አዎ 2. የለም ⟶	ክፍል 8
711	ለጥያቄ 710 መልስዎ አዎ ከሆነ፤ በየምን ያክል ጊዜ ያጨሳል?	1. በየቀኑ 2. ሳምንታዊ 3. ወርሃዊ 4. ከወርሃዊ በታች 88. አላውቅም	
712	ለጥያቄ 710 መልስዎ አዎ ከሆነ፤ ለስንት ዓመታት አጭሷል?	----------------------ዓመታት	
713	ለጥያቄ 710 መልስዎ አዎ ከሆነ፤ በአማካይ በቀን ስንት ሲጋራዎችን ያጨሳል?	----------------------ሲጋራዎች	

ክፍል 8፡ በቃለመጠይቁ ወቅት በማየት ብቻ የሚመለሱ

ተ.ቁ.	ሊታዩ የሚችሉ ተለዋዋጭ ባህርያት	አዎ	የለም	አይመለከተውም
	ቤት			
801	ቤቱ መስኮት አለው?	1	2	88
802	የቤቱ መስኮት በጉብኝቱ ወቅት ክፍት ነበር?	1	2	88

803	ቤቱ ለተፈጥሮአዊ የአየር ዝውውር የሚያገለግል ክፍት ቦታዎች አሉት?	1	2	88
804	በቤቱ ውስጥ ያሉት ክፍት ቦታዎች ለአየር ዝውውር በቂ ናቸው?	1	2	88
805	ቤቱ ውስጥ በአግባቡ የሚሰራ የጭስ ማስወገጃ ቱቦ አለው?	1	2	88
806	የቤቱ ጣሪያና ግድግዳ በጭስ ምክንያት ጠቁሮ ይታያል?	1	2	88
	ኩሽና ቤት			
807	ኩሽና ቤቱ መስኮት አለው?	1	2	88
808	የኩሽና ቤቱ መስኮት በጉብኝቱ ወቅት ክፍት ነበር?	1	2	88
809	ኩሽና ቤቱ ለተፈጥሮአዊ የአየር ዝውውር የሚያገለግል ክፍት ቦታዎች አሉት?	1	2	88
810	በኩሽና ቤቱ ውስጥ ያሉት ክፍት ቦታዎች ለአየር ዝውውር በቂ ናቸው?	1	2	88
811	ኩሽና ቤቱ የሚሰራ የጭስ ማስወገጃ ቱቦ አለው?	1	2	88
812	የኩሽና ቤቱ ጣሪያና ግድግዳ በጭስ ምክንያት ጠቁሮ ይታል?	1	2	88
813	የኩሽና ቤቱ ከዋናው መኖሪያ ቤት ያለው ርቀት በቂ ነው? (የኩሽና ቤቱ ከመኖሪያ ቤቱ የተለየ ከሆነ)	1	2	88
814	የኩሽና ቤቱ ከምግብ ማብሰያነት ውጭ ለሌላ ኣገልግሎት ይውላል?	1	2	88
815	የኩሽና ቤቱ ንጹህ ነው?	1	2	88
	የሚታዩ ተግባራት			
816	በጉብኝቱ ወቅት እየተገለገሉበት ያለው የሃይል ምንጭ ምን ዓይነት ነው?	1. ኤሌክትሪክ 2. የሲሊንደር ጋዝ ምድጃ/ ባዮጋዝ 3. ኪሮሲን/ጋዝ 4. ክሰል 5. እንጨት, ገለባ, የእፅዋት ተዋጽኦ, ኩበት, ሳር, ቁጥቋጦ 99. ሌሎች (ይገለጽ)-----		
817	በጉብኝቱ ወቅት እየተገለገሉበት ያለው የምድጃ ምን ዓይነት ነው?	1. ክፍት ምድጃ ጭስ ማውጫ የሌለው 2. ክፍት ምድጃ ጭስ ማውጫ ያለው 3. ዝግ ምድጃ (የተሻሻለ)ጭስ ማውጫ ያለው 4. የኤሌክትሪክ ምድጃ/ምጣድ 99. ሌሎች (ይገለጽ)-----		

818	በጉብኝቱ ወቅት እያበሰሉ የነበረው ምግብ ምን ዓይነት ነው?	1. አበሰሉ አልነበረም 2. እንጀራ መጋገር 3. ወጥ መስራት 4. ዳቦ መጋገር 5. ዉሃ ማሞቅ 99. ሌላ (ይገለፅ)---
819	በጉብኝቱ ወቅት በኩሽና ቤቱ ውስጥ ምግብ እየበሰለ ባለበት ጊዜ ስንት ህፃናት ነበሩ?	1. ምንም አልነበሩም 2. አንድ 3. ሁለት 4. ሶስትና ከዚያ በላይ
820	ምግብ በምታበስልበት ጊዜ ህፃን ልጅ በጀርባዋ አዝላ ነበር?	1. አዎ 2. የለም
821	እባክዎ፤ የኩሽና ቤቱን አየር የመዘዋወር ሁኔታ ደረጃ ይስጡት	1. ዝቅተኛ (ባለ አንድ በር ብቻ ስለሆነ) 2. መካከለኛ (ባለ አንድ በር እና አንድ መስኮት ብቻ ስለሆነ) 3. ጥሩ (ከአንድ በር እና መስኮት በላይ ስለሆነ)

ስለ ትብብርዎ በጣም አመሰግናለሁ!!

CENSUS QUESTIONNAIRE

በወላይታ ሶዶ ከተማ ውስጥ በማገዶ ጭስ ምክንያት የሚከሰት የቤት ውስጥ የአየር ብክለት መጠንና በህፃናት ላይ ስለሚያሰከትለው አጣዳፊ የመተንፈሻ አካላት ችግሮችና ምልክቶች የዳሰሳ ጥናት

ጥያቄ1	ጥያቄ2	ጥያቄ3
ህፃኑ በባለፉት ሁለት ሳምንታት ውስጥ በአንዱ ቀን ሳል አስሎት (ሳል አሞት) ነበር? 1. አዎ 2. የለም 3. አላውቅም	አዎ ካሉ፤- ሳል ማሳሉን ተከትሎ፤ህፃኑ ለመተንፈስ ተቸግሮ ነበር ወይም አተነፋፈሱ ከተለመደው ስርዓት ፈጣን፤አጭር፤ቁርጥ ቁርጥ የሚል ነበር? 1. አዎ 2. የለም	ለሳሉም ሆነ ለአተነፋፈሱ ችግር ምክር ወይም የህክምና እርዳታ አግኝተዋል? 1. አዎ 2. የለም

ተ.ቁ.	የቤት መለያ ቁጥር	የቤቱ አባውራ ስም	ቀበሌ	ሰፈር	**ጥያቄ1**	**ጥያቄ2**	**ጥያቄ3**
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ANNEX-III: PARTICIPANTS INFORMATION SHEET AND CONSENT

PARTICIPANTS INFORMATION SHEET

Assessment ofthe level of indoor air pollution from biomass fuel use and its effect on acute respiratory infection in under-five years children, Wolaita Sodo, Ethiopia

Introduction: Greeting; this is _______________ and I am here for collecting information for the study which is conducted by Mr. Amha Admasie (a PhD candidate at Addis Ababa University, school of public health). He is conducting the research to find out the effect of indoor air pollution from households of biomass fuel users on acute respiratory infection in under-fivechildren. We will give you some information on how to participate on the basis of which you will decide on whether or not you will participate in the study.

Title of the study: "Assessment of the level of indoor air pollution from household use of biomass fuel and its effect on acute respiratory infection in under-fivechildren, Wolaita Sodo, Ethiopia"
Objective: The objective of this study is to assess the level of indoor air pollution from household use of biomass fuel and its effect on acute respiratory infection in under-fivechildren in Wolaita Sodo, Ethiopia.

Benefits: This study will not give any direct benefit to the participants; but the information which will be gained from the participants will help the town health office and other stake holders working in such area to design an appropriate intervention.

Risks: The study will not impose any risks on the participants, except spending few minutes for interviewing and measurements of pollutants in your kitchen.

Right of the respondents: You will be invited to participate on this study voluntarily. At any time you can quit from giving answer for the questionnaire that you not willing to answer or even can withdraw any time you want without being affected.

Confidentiality: Filled questionnaires will not be accessible to anybody other than the study members and any information that you will give will not be linked to personal identification and be kept confidential. Pollutant level of your kitchen and your child nutritional status will be measured using measuring materials. Photos of kitchen arrangements and facilities will be taken and used for information dissemination. However, your name and the location will not be indicated which will keep confidentiality.

Whom to contact: If you will have any question about the research please contact Mr. Amha Admasie (PI), at the School of Public Health of Addis Ababa University, at 0911-364739.

CONSENT FORM CONSENT FORM

With the due understanding of the aforementioned information, would you be willing to participate in the study?

Yes ☐ (proceed to sign and interview No ☐ Thank and terminate the interview)

I, _______________________hereby give my consent to participate in this survey. I have been given the necessary information about the research in a language I understand. I have also understood that I can withdraw my consent any time without penalty of loss of benefits.

Signature/Finger print of the participant
Signature/Finger print ____________________Date ___________________

Signature of the interviewer
Name ______________________Signature ________________ Date __________

Supervisors/Researcher remark and signature

Name ______________________ Signature _______________ Date __________

የአማርኛ ትርጉም

በወላይታ ሶዶ ከተማ ውስጥ በማገዶ ጭስ ምክንያት የሚከሰት የቤት ውስጥ የአየር ብክለት መጠንና በህፃናት ላይ ስለሚያስከትለው አጣዳፊ የመተንፈሻ አካላት ችግሮችና ምልክቶች የዳሰሳ ጥናት

1. **ለጥናቱ ተሳታፊዎች የመረጃ ቅፅ**

መግቢያ: ሰላምታ፡ እኔ ______________________________________ እባላለሁ፡፡ አሁን የመጣሁትም የአዲስ አበባ ዩኒቨርሲቲ በህብረተሰብ ጤና ትምህርት ቤት እጩ ዶክተር በሆኑት በአቶ አምሃ አድማሴ እየተሰራ በሚገኘው ጥናት መረጃ ለመሰብሰብ ነው፡፡ ጥናቱ የሚካሄድባቸው ቦታዎች በወላይታ ሶዶ ከተማ ውስጥ በሚገኙ የመኖሪያ ቤቶች ሲሆን የተመረጡትም በዕጣ ነው፡፡ ጥናቱ በአዲስ አበባ ዩኒቨርሲቲ የጤና ሳይንስ ኮሌጅ የጥናትና ምርምር ስነምግባር ገምጋሚ ተቋም ምክር ቤት ፤ በወላይታ ሶዶ ከተማ አስተዳደርና በወላይታ ሶዶ ዩኒቨርሲቲ በሚባሉ ተቋማት ፍቃድ የተሰጠው ነው፡፡ በጥናቱ በወላይታ ሶዶ ከተማ ውስጥ የሚገኙ ነዋሪዎች እንዲሳተፉ እየተጠየቁ ነው/ተጠይቀዋልም፡፡ ስለዚህ የእርስዎም ልጅ በዳሰሳ ጥናቱ ላይ እንዲሳተፍ ጥሪ እናቀርብለዎታለን፡፡ ስለ እያንዳንዱ ህፃን ወላጅ ወይም አሳዳጊ መጠይቁን እንዲሞሉ ይጠየቃሉ፡፡ በዚህ የመረጃ መስጫ ቅፅ ባገኙት ግንዛቤ መሰረት ልጅዎ የጥናቱ አካል እንዲሆን ከተስማሙልን፤ "አዎ ተስማምቻለሁ" ከሚለው ቦታ ላይ ምልክት በማድረግ ፍቃደኛነዎትን ይግለፁ፡፡ በመቀጠልም ከዚህ የመረጃ መስጫ ቅፅ ጋር ተያይዞ የቀረበውን መጠይቅ እንዲሞሉ እንጠይቃለን፡፡

የጥናቱ ርዕስ: "የህፃናት ጤናና ተያያዥ ጉዳዮች"

የጥናቱ ዓላማ: - ዓለማውም፡ በማገዶ ጭስ ምክንያት የሚከሰት የቤት ውስጥ የአየር ብክለት መጠንና በህፃናት ላይ ስለሚያስከትለው አጣዳፊ የመተንፈሻ አካላት ችግሮችና ምልክቶች መለየትና ማረጋገጥ ነው፡፡

ጠቀሜታ: - ጥናቱ ለተሳታፊዎች በቀጥታ ምንም ዓይነት ጥቅም አይሰጥም፡ ነገር ግን ከተሳታፊዎች የሚገኘውን መረጃ መነሻ በማድረግ ተሰማሚ የማስተካከያ እርምጃ ለመውሰድ ይረዳል፡፡

ስጋትና አለመመቸት: - ጥናቱ በተሳታፊዎች ላይ መጠይቁን ለመሙላት የተወሰኑ ደቂቃዎችን ከመውሰዱ ውጭ ምንም ዓይነት ስጋት አያስከትልም፡፡

የተሳታፊዎች መብት: በዚህ ጥናት መሳተፍ በፍቃደኝነት ላይ የተመሰረተ ነው፡፡ ስለሆነም በማንኛውም ሰዓት መጠይቁን የማቋረጥ እንዲሁም በመጠይቁ ውስጥ መመለስ የማይፈልጉትን ጥያቄ የመዝለል፤ በተጨማሪም ከጥናቱ ተሳታፊነት ያለምንም ጉዳት/ጫና የመውጣት መብት አለዎት፡፡

ጥቅማጥቅሞች: በጥናቱ ለመሳተፍ ምንም ዓይነት መደለያ ወይም ጥቅማጥቅሞች አይሰጡም፡፡

ምስጢራዊነት: -በተሳታፊዎች የተሞሉት መጠይቆች ከአጥኚው/ተመራማሪው አካል ውጭ ለሌላ ለማንም ተላልፎ አይሰጥም፡፡ እርስዎ የሰጡት መረጃ በምንም ዓይነት መልኩ ከግል ማንነትዎ ጋር አይያዝም የሰጡትም መረጃ በምስጢር ይያዛል፡፡ የምግብ ማብሰያ ቦታዎችን ሁኔታ ለማየትና መረጃዎችንም ለሌሎች ለማሰተማር ሲባል የምግብ ማብሰያ ቦታዎችን ፎቶዎችን እናነሳለን፡፡ ሆኖም ግን ስምዎና ፎቶዎቹ የተነሱበት ቦታ በፎቶዎቹ ላይ አይገለፅም፤ በምስጢርም ይያዛል፡፡

ለበለጠ መረጃ: እባክዎ ጥናቱን በተመለከተ ምንም ዓይነት ግልፅ ያልሆኑ ጥያቄዎች ካሉዎት፡ በአዲስአበባ ዩኒቨርሲቲ የህብረተሰብ ጤና ትምህርትቤት፤ አቶ አምሃ አድማሴ (ዋናተመራማሪ)፤ የስልክ ቁጥር 0911-364739; ዶ/ር አበራ ቁሜ (አማካሪ) የስልክ ቁጥር 0911-882912 እንዲሁም በአዲስ አበባ ዩኒቨርሲቲ ጤና ሳይንስ ኮሌጅ የተቋማዊ የምርምር ስነምግባር ቦርድን በስልክ ቁጥር 011-896-1396 ደውለው ማነጋገር ይችላሉ።

ቅጥያ 2: የፍቃደኝነትማሳወቂያቅፅ

ውድ ወላጅ/አሳደጊ

በዚህ ጠቃሚ በሆነና በህፃናት ጤና ዙሪያ ላይ ዳሰሳ በሚያደርገው ጥናት ልጅዎ እንዲሳተፍ የእርስዎንም ፍቃድ እንጠይቃለን። በዚህ ጥናት ላይ መሳተፍ በፍቃደኝነት ላይ የተመሰረተ ነው። በጥናቱ ላይ ለመሳተፍ መስማማትም አለመስማማትም ይችላሉ። ከጥናቱ የሚገኘው ውጤት በኢትዮጵያ ውስጥ ለሚገኙና በህፃናት ላይ ስለሚከሰት የሳምባና ተያያዥ በሽታዎች ዙሪያ የመከላከልና የመቆጣጠር ስራዎችን ለሚሰሩ የጤና ባለሞዎች (የጤና አጠባበቅ ባለስልጣናት) እና አጋር ተቋማት በግብዓትነት ይውላል። በዚህ ጥናት መሳተፍ በልጅዎ ላይ ምንም ዓይነት ጉዳት አያስከትልም። ስለ እያንዳንዱ ህፃን ወላጅ ወይም አሳዳጊ መጠይቁን እንዲሞሉ ይደረጋል። በዚህ የመረጃ መስጫ ቅፅ ባገኙት ግንዛቤ መሰረት ልጅዎ የጥናቱ አካል እንዲሆን ከተስማሙልን፤ ከዚህ የመረጃ መስጫ ቅፅ ጋር ተያይዞ የቀረበውን መጠይቅ ይሙሉልን። ስለ ልጅዎ የሰጡት መረጃም በምስጢር ይያዛል።

ከላይ ባገኙት የመረጃ ግንዛቤ መሰረት ልጅዎ የጥናቱ አካል እንዲሆን ይስማማሉ?

አዎ ተሰማምቻለሁ -------------------------------- አይ አልተስማማሁም --------------------------------

የተሳታፊው ፊርማ _______________________ቀን ______________________

የቃለ መጠይቅ አድራጊው: ስም _________________________ፊርማ _______________ቀን________________

የተቆጣጣሪው/የተመራማሪው አስተያየት--

ስም _________________________ ፊርማ _________________ ቀን ____________________

ANNEX-IV: DECLARATION

Letter of declaration

I, the undersigned, declared that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation, have been fully acknowledged.

Name: **Amha Admasie**

Signature: ___________________________________

Date: _______________________________________

Place: Addis Ababa University, School of Public Health

This dissertation has been submitted for examination with my approval as supervisor

Name: Dr. Abera Kumie (PhD)

Signature: ___________________________________

Date: _______________________________________