EFFECT OF BIOMASS FUEL USE ON RESPIRATORY MORBIDITIES AMONG WOMEN AND UNDER FIVE CHILDREN IN RURAL JODHPUR

Thesis

Submitted to

All India Institute of Medical Sciences, Jodhpur

In partial fulfilment of the requirement for the degree of

DOCTOR OF MEDICINE (MD)

(COMMUNITY MEDICINE)

JUNE 2022

AIIMS, JODHPUR **DR. SHAIMA ABDUL JABBAR**

DEPARTMENT OF COMMUNITY MEDICINE AND FAMILY MEDICINE

ALL INDIA INSTITUTE OF MEDICAL SCIENCES, JODHPUR

CERTIFICATE

This is to certify that this thesis entitled "**Effect of biomass fuel on respiratory morbidities among women and under five children in rural Jodhpur**" is an original work of **Dr. Shaima Abdul Jabbar** carried out under our direct supervision and guidance at Department of Community Medicine & Family Medicine, All India Institute of Medical Sciences, Jodhpur.

Guide
Dr. Neeti Rustagi
Additional Professor
Department of CMFM
AIIMS Jodhpur

Co-Guide
Dr. Suman Saurabh
Assistant Professor
Department of CMFM
AIIMS Jodhpur

Co-Guide
Dr. Naveen Dutt,
Additional Professor,
Department of Pulmonology
AIIMS Jodhpur

Co-Guide
Dr Prawin Kumar
Associate Professor
Department of Pediatrics
AIIMS Jodhpur

ALL INDIA INSTITUTE OF MEDICAL SCIENCES, JODHPUR

DECLARATION

I, hereby declare that the work reported in the thesis entitled **"Effect of biomass fuel on respiratory morbidities among women and under five children in rural Jodhpur"** embodies the result of original research work carried out by undersigned in the Department of Community Medicine and Family Medicine, All India Institute of Medical Sciences, Jodhpur.

I further state that no part of the thesis has been submitted either in part or in full for any other degree of All India Institute of Medical Sciences or any other institution/ University.

Dr. Shaima Abdul Jabbar

Junior Resident

Department of Community Medicine & Family Medicine

All India Institute of Medical Sciences, Jodhpur

ACKNOWLEDGEMENT

“Walk not on the earth in arrogance nor pride.” A verse I hold close to myself as a reminder about the compassion of the almighty to his beings. I am immeasurably indebted to Him, He who has guided me to where I am now and provided generously through my family and mentors.

To the person who dreamt of a doctor in the family, my grandfather **Mr Moosakutty Rowther,** I owe it to him for the instillation of that dream in his future generations.

I am indebted to my guide **Dr Neeti Rustagi** for guiding and putting up with me throughout the study. She provided me with the critical advice and valuable inputs I needed for the study's successful completion.

I am grateful to my co-guide **Dr Suman Saurabh**, who has always supported me through all parts of the research with his invaluable inputs even in the fine aspects of the research. He has been a constant support and an excellent teacher who always addressed all my doubts.

I am thankful to my co-guide **Dr Naveen Dutt** for providing the necessary support for training under the department of Pulmonology. I am thankful to my co guide **Dr Prawin Kumar** for his undeterred and selfless support for the development of the questionnaire.

I am grateful to **Dr. Pankaja Raghav**, the head of my department, for her guidance and assistance during the course of my studies, as well providing mental support.

I am immensely indebted to **Dr Arun Sharma** who provided much support and created the curiosity in me about this subject.

I cannot thank my family **Mr Abdul Jabbar, Mrs Bee Fathima, Mr Abdul Razak and Mrs. Abida Katali**, enough for believing in me and always being there supporting me in promoting my career.

I owe my deepest gratitude for my better half**, Mr. Jaseem VA**, who has always been by my side as a solid pillar, ensuring that my career advancement is not hampered.

I am much indebted to my son **Master Faizeen Valiyatt** who has endured my absence and put up with it for the last two and half years.

I thank my seniors **Dr Ankit Mittal, Dr Rehana and Dr Pritish** for their selfless support even during their busiest times. I would like to mention my dear friends and juniors **Dr Vetrivel, Dr Aswathy and Dr Harimadhav** for their help and being by my side in times of stress.

I would be failing in my duty if I am not thanking **Mr Laxman** who has given his valuable time to help me traverse the village and reach out to the participants.

Dr. Shaima Abdul Jabbar

Table of Contents

List of tables

List of figures

List of abbreviations

ARI	Acute respiratory infection.
BC	Black carbon
BMF	Biomass fuel
CO	Carbon monoxide.
COPD	chronic obstructive pulmonary disease.
DALYs	Disability adjusted life years.
FEV1	Forced expiratory volume in one second
FVC	Forced vital capacity
GOI	Government of India
HAP	Household air pollution
IAP	Indoor air pollution.
IAQ	Indoor Air Quality Guidelines
ICS	Improved cookstoves
LPG	Liquified Petroleum Gas
LRS	Lower respiratory symptoms
MNREGA	Mahatma Gandhi national rural Employment guarantee act.
NAAQS	National ambient air quality standards.
NFHS	National Family Health Survey
PHC	Primary Health Centre
PM	Particulate matter
PMUY	Pradhan Mantri Ujjwala Yojana
SDG	Sustainable Development Goals
SHG	Self help groups
TCS	Traditional cookstoves
URS	Upper respiratory symptoms
WHA	World Health Assembly
WHO	World Health Organization

SUMMARY OF THESIS

Background

Indoor air pollution within households is a serious health risk for 3 billion people who cook and heat their homes with biomass fuels[1]. It has been identified by the WHO as the second largest cause of morbidity after unsafe drinking water and sanitation. Exposure to indoor air pollution is high among women and children less than 5 years as they spend more time indoors[1].

Combustion of biomass fuels (wood products, dried vegetation, crop residues, aquatic plants, and even garbage produces airborne particulate matter and toxic compounds carbon monoxide, sulphur dioxide, nitrogen oxides, benzene, and formaldehyde[2]. These have been implicated in the pathogenesis of respiratory morbidities. Due to the risks of indoor air pollution, Pradhan Mantri Ujjwala Yojana (PMUY) had been launched in 2016 by the Government of India to provide connection of liquefied petroleum gas for cooking to those below poverty line to safeguard the health of women and children. The scheme has benefitted 63 lakh families of Rajasthan according to Ministry of Petroleum and Natural Gas[3]. However, in a preliminary survey of 20 houses done at a rural area of Jodhpur it was found that seven of the 20 houses used only wood as the primary source of fuel for cooking as they had not received the provision of PMUY , the remaining 13 houses used both wood and liquified petroleum gas as fuel.

Aim

Objectives

Our objectives were to –

a) assess the effect of biomass fuel use on respiratory morbidities among adult women and under five children in rural Jodhpur,

b) compare air pollutant levels between households using biomass fuel and households not using biomass fuel in the background of other indoor air pollutants and

c) study the awareness regarding Pradhan Mantri Ujjwala Yojana among the households currently using biomass fuels.

Methodology

The study was done in a village of Jodhpur district. This was a cross-sectional study with a sample size of 480. Women who visited Dhawa PHC were recruited for the study after informed consent. Women were assessed for respiratory symptoms. The under five children in their houses were enlisted and information regarding ARI (acute respiratory infection) among them was collected. The households were assessed in terms of the type of stove that were used by them – traditional mud stove, LPG stove or mixed fuel users, the location of stove w.r.t. kitchen. The awareness with regard to Pradhan Mantri Ujjwala Yojana among the households and their utilisation/availing of the programme was assessed. The knowledge of the Pradhan Mantri Ujjwala Yojana programme among participants, as well as their adoption of the programme, were evaluated.

Results:

A total of 480 women were recruited in the study of which 95 were exclusive LPG users and 385 were using biomass fuel. The median age of the LPG using participants was 35 years which was higher compared to biomass users which was 30 years. LPG users primarily (41%) belonged to upper socio-economic class while majority of biomass users belonged to upper middle class (48.4%). Among biomass users 5.5% reported visiting doctor in the last 2 weeks for wheeze. Contrary to what was expected a larger proportion of LPG users had reported respiratory symptoms (41% had ever had trouble breathing and 43% ever experienced cough) due to smoke from cooking. This might be attributed to a move to LPG because cooking with biomass fuel is challenging. A higher proportion (44.4%) of children belonging to biomass using households reported having at least 1 ARI episode in last 3 months preceding survey while only 22.5% children of LPG using households reported the same.

Particulate matter concentrations were monitored in a total of 120 households. Complete 24-hour data was available for only 113 households. Among kitchen setups. , traditional mud stove users had considerably higher 24-hour mean PM2.5 and PM10 concentrations, 75.488 ± 24.54 µg/m^3 and 90.46 ± 27.25 µg/m^3 respectively as compared to mixed stove (38.67 ± 29.99 µg/m^3 and 50.95 ± 44.23 µg/m^3) and LPG stove (22.01.± 15.21 µg/m^3 and 28.09.± 22.24 µg/m^3). PM2.5 concentrations were highest in inside kitchens using biomass 70.65 ± 33.91 µg/m^3 as compared to outside kitchens. which was 114.45 µg/m^3.

The study also assessed the awareness regarding Pradhan Mantri Ujjwala Yojana And its adoption. It was found that more than 50% of the population were aware of the programme. Around 50% had applied for it and nearly 50% had received the connection.

Conclusion:

Fuel choice significantly affects indoor air particulate matter concentration and health of women causing increased frequency of respiratory symptoms among women and children as observed in current study.

In this study we have investigated the determinants of indoor air pollution and exposure to indoor air pollution in rural Jodhpur. Although participants' concern of COVID 19 isolation may have resulted in a lower proportion of self-reported symptoms, LPG users reported a larger proportion of having ever had respiratory morbidities. This implied that symptomatic biomass fuel consumers were switching to cleaner fuel.

LPG adoption and households with continued use of exclusive LPG experiences lower 24 hourly and hourly mean particulate matter concentration. Integrated policies to enable sustained energy access and adoption will have clear health benefits, influencing the burden of NCD’s in rural India.

Emphasis on LPG use can play an essential role in achieving reduction in household air pollution by 50%, as envisaged under the NCD prevention targets in India.

PMUY provided LPG connections and cylinders to around half of the participants, yet the bulk of them continue to use biomass fuel. This necessitates a reassessment of the programme or the establishment of new policies to enable marginalised individuals to utilise cleaner fuels, allowing the SDG and WHO objectives to be attained in the long run.

Chapter 1: INTRODUCTION

With the advent of newer technologies like hydropower, nuclear power as well as extensive use of fossil fuels the last two centuries has seen a considerable shift of energy sources. Currently most of the direct energy needs of human society is being met by these sources. But a majority of the world's population still rely on traditional fuels like fuelwood, cow dung and crop residue, especially for household cooking[4].

Indoor air pollution within households is a serious health risk for around 3 billion people who cook and heat their homes with biomass fuels[5]. It has been identified by the WHO as the second largest cause of morbidity after unsafe drinking water and sanitation. Indoor air pollution, from traditional fuels (biomass and coal) and cooking stoves, is associated with an increase in the incidence of respiratory infections, including pneumonia, tuberculosis and chronic obstructive pulmonary disease, low birthweight, cataracts, cardiovascular events, and all-cause mortality both in adults and children[6]. The poorest and most vulnerable populations in developing countries are generally the most exposed to indoor air pollution from biomass combustion[7]. Exposure levels are usually much higher among women as they do most of the cooking and among young children because they are often carried or held on their mothers back or lap during cooking[8]. They are exposed to particle concentrations of 500-1500 μ_g / m^3 during cooking which are far above the normal levels as well as interim targets prescribed in WHO's air quality guidelines[9]. According to the Global burden of disease 2019, 3.6% of all DALYs are attributed to household air pollution[10].

The major risk factors of childhood pneumonia are biomass fuel used for cooking, crowded houses, and parental smoking. Particulate matter (soot) inhaled from household air pollution is responsible for nearly half of all pneumonia fatalities in children under the age of five[11]. Combustion of biomass fuels (wood products, dried vegetation, crop residues, aquatic plants) and even garbage produces airborne particulate matter and toxic compounds (carbon monoxide, sulphur dioxide, nitrogen oxides, benzene, and formaldehyde).These have been implicated in the pathogenesis of respiratory morbidities[12,13].

The health concerns associated with particulate matter with diameters of 10 to 2.5 microns (μm) (PM10 and PM2.5, respectively) are of significant public health concern. PM2.5 and PM10 may both penetrate deep into the lungs, but PM2.5 has the ability to reach the circulation, causing cardiovascular and respiratory effects as well as impacting other organs[9].

As per the recent WHO Global Air Quality Guidelines 2021, the recommended AQG level for 24-hour average is 15mcg/m3 for PM2.5 and 45mcg/m3 for PM10. Interim targets are also given, these are to be used as stepping stones in the process of reducing air pollution to levels that meet the air quality guidelines[9].

The World Health Assembly (WHA) unanimously approved a resolution in 2015 to expedite global action to combat household air pollution for the first time. The World Health Organization (WHA) issued a "Roadmap for Enhanced Action" the following year, urging stronger cross-sector collaboration to address the health consequences of air pollution[9].

Household energy and air pollution are given major importance in the Sustainable Development Goals (SDGs). SDG 7 states explicitly that by 2030, "ensure access to affordable, reliable, sustainable and modern energy for all". The percentage of the world population that relies mostly on clean fuels and technology is one measure for gauging progress toward this ambitious goal. The SDG targets reflect that household energy is an important consideration in many facets of human development, from health (SDG 3) to sustainable urban environments (SDG 11) to gender equality (SDG 5) to climate action (SDG 13) and is not just the province of environment and energy ministries[14].

About 84.65% of rural families and 21.49% of urban families are using biomass as the main energy source of cooking in India according to 2011 Census[15]. According to the Energy progress report (2021) of the SDG 7 tracker, 64% of the total population of India has access to clean energy for cooking but there is a clear urban-rural divide in the access with only 48% of rural population having access to clean fuel for cooking as compared to 90% of urban population[16].

IAP is dependent upon multiple determinants such as type of fuel used for cooking, varied types of kitchens set ups, structural characteristics of houses, household ventilation, location of the house, geographical conditions and exposure time. Among these factors, type of fuel and varied kitchen setups affects IAP levels significantly[6].

Contrary to popular belief the air quality in rural areas are also polluted, they are exposed to both outdoor and indoor air pollution. Under the National Clean Air Program, which was launched in India in 2019, they have proposed to enhance the ambient air quality and emissions monitoring capacity in India by 2024. They aim to expand the monitoring network to 50 rural areas with at least one station and promote programs on indoor air pollution monitoring with special focus on managing household fuel combustion[17].

Due to the risks of indoor air pollution, Pradhan Mantri Ujjwala Yojana (PMUY) had been launched in 2016 by the Government of India under Ministry of Petroleum & Natural Gas, a social welfare scheme, to provide connection of liquefied petroleum gas for cooking to women below poverty line so as to safeguard the health of women and children[18].The scheme was intended to increase the usage of LPG and reduce ill effects due to smoke on health, to reduce air pollution and deforestation . The scheme has benefitted 63 lakh families of Rajasthan according to Ministry of Petroleum and Natural Gas[3].

According to the NFHS-5 report, the percentage of families having clean cooking fuel has increased in virtually all states/UTs during the past four years (from 2015-16 to 2019-20). Only 43.2 % of the rural population has access to clean fuel for cooking, compared to 89.7% in urban areas[19].

This lack of access to clean fuels in rural areas puts them at a disadvantage of continued exposure to indoor air pollution which can cause respiratory illnesses among others. In this study we intend to assess the prevalence of indoor air pollution in households using biomass fuel and the prevalence of respiratory morbidities among women and children exposed to it. And how the programme of PMUY through providing clean fuels to the marginalized have fared in these rural areas.

Chapter 2: AIM AND OBJECTIVES

Aim

The aim of the present study was to assess the effect of biomass fuel use on respiratory morbidities among adult women and under five children in rural Jodhpur.

Objectives

The objectives of the present study were to:

a) assess the effect of biomass fuel use on respiratory morbidities among adult women and under five children in rural Jodhpur,

b) compare air pollutant levels between households using biomass fuel and households not using biomass fuel in the background of other indoor air pollutants, and

c) study the awareness regarding Pradhan Mantri Ujjwala Yojana among the households currently using biomass fuels.

Chapter 3: REVIEW OF LITERATURE

Throughout the study period, review of literature was conducted to determine what was previously done in the subject of indoor air pollution and the scope for future research. Earlier research was done was based in cities and in other states of India. The reach of Pradhan Mantri Ujjwala Yojana programme could not be appreciated from any studies. The main websites accessed for literature search was PubMed and Google Scholar. For searching articles, the keywords used were: Biomass fuel, indoor air pollution, particulate matter, PM2.5 and PM10, respiratory symptoms, respiratory illness, ARI, women, under five children, Pradhan Mantri Ujjwala Yojana, lung function tests, pulmonary function tests, spirometry, etc. Manual search for literature was done in the central library of AIIMS Jodhpur

3.1 Effect of biomass fuel use on respiratory morbidities

Priscilla Johnson et al 2011[20] conducted a study to estimate the prevalence of COPD and its associated factors among non-smoking rural women in Tiruvallur district of Tamil Nādu. It was a cross-sectional study was done among 900 non-smoking women aged above 30 years, from 45 rural villages of Tiruvallur district. COPD assessments were done using a combination of clinical examination and spirometry. The COPD prevalence estimate obtained in this study population of Indian, rural, and primarily biomass-using women of 30 years of age stands at 2.44%, which is higher than the world prevalence of 0.8% .

760 non-smoking, non-pregnant women aged 15 years and above exposed to domestic smoke from cooking fuels from an early age from Nagpur were recruited by **Sukhsohale et al 2013**[21] for assessing respiratory and other morbidities associated with use of various types of cooking fuels. It was found that symptoms like eye irritation, headache, and diminution of vision were found to be significantly higher in biomass users ($p < 0.05$). Pulmonary function test abnormality, chronic bronchitis, and cataract in biomass users was significantly higher than other fuel users ($p < 0.05$).

Dutta et a 2014[22] studied the association of biomass smoke on respiratory function and hypertension among never smoking 480 premenopausal women of 10 villages of West Bengal. They assessed PM levels, lung functions and respiratory symptoms. Significant reduction of lung function was a common finding in rural women who used to cook with highly polluting biomass fuel. Compared with control, about 64 % of biomass using rural women had reduced lung function. Biomass-using women exposed to smoke for more than 10,000 hour-years exhibited higher prevalence of respiratory symptoms, both URS (upper respiratory symptoms) and LRS (lower respiratory symptoms). There was significant difference in the prevalence of hypertension and prehypertension between biomass users and non-biomass users ($p <0.001$).

Raj T et al in 2014[23] conducted a study in asymptomatic women exposed to biomass fuel to evaluate forced expiratory lung volume among them. He assessed the lung function of women exposed to biomass fuel and women using other sources of fuels. He found that 3/4th of asymptomatic women using biomass fuel had impaired lung function which was evident from the reduction in forced expiratory lung volumes. The relative risk was found to be 4.5 times.

In a nation-wide study conducted by **Agarwal et al in 2014**[24] about the effect of indoor air pollution due to biomass smoke on the prevalence of self-reported asthma among men and women, it was found that adult women living in households using biomass and solid fuels have a significantly higher risk of asthma than those living in households using cleaner fuels (OR: 1.26; 95%CI: 1.06-1.49; $p = .010$), even after controlling for the effects of a number of potentially confounding factors.

In a study by **Mukherjee S et al**[25], in eastern part of India about Respiratory Symptoms, Lung Function Decrement and Chronic Obstructive Pulmonary Disease on premenopausal women using biomass fuel, it was found that the prevalence of upper and lower respiratory symptoms were more among LPG users (50.9 % Vs 28.5% and 71.8 versus 30.8%. The decline in lung function values were positively associated with PM10 and PM2.5 values in indoor air. COPD was found to be more among those who used biomass (4.6%) than LPG (0.6%).

Panigrahi A et al in 2018[26] conducted a community based cross sectional study in Odisha to determine the prevalence of chronic bronchitis and air flow obstruction, and its association with household fuel use. The sample was 1120 randomly selected never smoking women with age ranging between 18-49 years. They found that the odds ratio of the association of chronic bronchitis and airflow obstruction with solid biomass fuel were 7.3% and 22.4% respectively. They also found that an increase in PM2.5 levels was associated with a significantly lower FEV1/ FVC.

A study on the effect of biomass fuel on pulmonary function was conducted by **Rabha R et al in 2018**[27] in three villages of Assam. It was done on 266 biomass using and 82 LPG using non-smoking women. The study showed that women using wood as cooking fuel had lower FVC and FEV1 than LPG users ($p < 0.001$).

Kurmi OP et al in 2013[28] conducted a study to assess the effects of biomass smoke exposure on lung function among adults exposed to biomass smoke and those not exposed. This was a cross-sectional study done in Kathmandu valley among a sample of 1648 adults. A significant reduction in lung function was identified across all age groups exposed to biomass with mean FEV1 being 2.65 as compared to non-biomass group which was 2.83.

In a community based cross-sectional study among 1705 women by **Sana A et al (2019)**[29] in Burkina Faso, it was found that respiratory outcomes were seen in women who use biomass for cooking as compared to LPG . The ORs where Chronic cough: 1.17, Chronic phlegm: 1.61% , Wheeze : 1.37 , Shortness of breath : 1.30. Also, the odds ratio of women with breathing difficulties among those who cook for more than 2hrs was 1.56.

3.2 Particulate matter concentrations in households

In a study by **Arif et al (2021)**[30] daily concentrations of BC, PM2.5 and PM10 were monitored from different types of biomass user's households during January 2018 to December 2019 to assess indoor air quality in three districts **(Sitapur, Patna and Murshidabad**) of Indo-Gangetic Plains (IGP) where approximately, 96% of rural families rely on biomass cooking. The 24-h continuous monitorings of BC, PM10 and PM2.5 were executed in 120 households (60 biomass and 60 liquefied petroleum gas (LPG) user's households) for monitoring the indoor air quality (IAQ) and to examine the influence of LPG during January 2018 to December 2019. The highest mass concentrations were observed in biomass user's households and cow-dung cake users due to low calorific value. The observed mass concentrations of PM10 And PM2.5 Were higher than the NAAQS threshold limit on a daily basis in all families of the study area. The daily mean mass concentrations of both PM2.5 and PM10 were within the threshold limit of NAAQS in the LPG user's homes. However, about 30.13% of PM10 and

35.89% PM2.5 data exceeded the threshold limit on a daily basis in biomass user's homes.

Huang et al (2021)[31] assessed personal exposure of PM2.5 and PAH in 60 biomass using households of **Sichuan Province East Tibetan plateau**. The typical stove used in this area was a built-in place brick stove with an outdoor chimney. The personal daily inhalation exposure levels measured by personal samplers were 121 ± 96µg/m3, 101 ± 78µg/m3 and 52 ± 48µg/m3 for PM1.0, PM2.5 and PM10 respectively. The PM2.5 exposure level exceeded the national daily ambient PM2.5 standard of 75µg/m3. The PM exposure contributed to 54% of morbidity of acute lower respiratory tract infections and 30% of mortality caused by COPD, 38% of lung cancer,30% of ischemic heart disease and 53% of stroke, respectively.

Stapleton et al (2020)[32] assessed the pulmonary functions of female cooks and quantified exposures in 34 kitchens of **Thanjavur, Tamil Nadu**. Daily PM2.5 (UPAS) concentrations in primary kitchens ranged from 18 to 732µg/m^3. Fuel-type predicted PM2.5 concentrations, with biomass kitchens having significantly greater concentrations ($p = 0.02$). PM2.5 was greater in biomass kitchens than LPG kitchens (p = 0.02).
Arithmetic mean 24-h PM2.5 was 120 µg/m3 (SD= 162), which is slightly higher but similar to previously reported LPG and biomass fuel 24-h PM2.5 in rural Tamil Nadu (mean = 105 ± 114µg/m3) (Balakrishnan et al., 2018) and greater than the World Health Organization guideline of 25µg/ m3 (WHO, 2006).

A detailed exposure assessment of PM2.5, CO, and BC to evaluate the influence of household characteristics on HAP exposures in **Puno, Peru** was done by **Fandino del rio et al (2020)**[33]**.** It was done in 180 women who used biomass daily for cooking. Average daily kitchen area PM2.5 concentrations were 1205µg/m3 (422-1824µg/m3), approximately 50 times the WHO indoor daily guideline (25µg/m3) and more than 15 times the most flexible interim WHO target of 75µg/m3.

A cross sectional study was done by **Kephert et al (2020)**[34] **in Peru** to assess the association between indoor air pollution and cardiometabolic health. Daily use of biomass cookstoves was reported by 46.2% of all participants and varied by site, from very low use in Lima (5.7%) and urban Puno (5.4%) to moderate use in Tumbes (27.2%) and near-universal use in rural Puno (96.5%). High concentrations of indoor PM2.5 across all four settings was found of PM2.5 daily average (in µg/m3): Lima 41.1 ± 1.3, Tumbes 35.8 ± 1.4, urban Puno 14.1 ± 1.7, and rural Puno 58.8 ± 3.1.

As part of a cross sectional study in **Pakistan** a study was conducted by **Fatmi et al (2020)**[35] to compare the concentrations of indicator pollutants in kitchens where biomass was used with those in kitchens that used natural gas (a cleaner fuel), and to investigate other factors that might impact on levels of pollution. They measured PM2.5 and/or CO in random subsets of 20 households that used biomass and 19 that used natural gas. Daily average concentrations of PM2.5 ranged from 59 to 875 µg/m3 in households using biomass and from 25 to 172 µg/in households cooking with natural gas.

Benka-Coker et al (2020)[36] performed a study to evaluate and compare wood-burning traditional and Justas cookstoves (the latter of which had an engineered combustion chamber and chimney) in **rural Honduras** as part of a larger study. 47 samples were collected, 30 were collected in households that used a traditional cookstove and 17 were collected in households that used a Justa cookstove. Households using traditional primary stoves had higher PM2.5 concentrations (median: 130 µg/ m3; IQR: 48–250 µg/m3; n=15) compared to households using Justa stoves (median: 66 µg/m3; IQR: 44–97 µg/m3; n=12). The mean 24-hour average PM2.5 concentrations exceeded the World Health Organization (WHO) air quality guideline of 25µg/m^3 for cookstove types.

A comparative assessment of the impact of traditional cookstoves (TCS) and improved cookstoves (ICS) coupled with the characteristics of kitchen was conducted by **Sharma et al (2019)**[37] in two villages of **Jagdishpur, Uttar Pradesh** to estimate the PM (PM10, PM2.5, PM1) concentrations in the micro-environments of kitchen. The mean concentration of PM2.5 and PM1 for TCS in an enclosed, semi-enclosed and open kitchen was 866, 653, 292 and 226, 174, 118 µg/ m3, respectively. However, the post intervention of ICS, average concentration of PM10, PM2.5 And PM1 for enclosed, semi-enclosed and open kitchen was (861,386 and 307), (391, 158 and 119), (506, 109 and 80 µg/ m3), respectively. Intervention of ICS resulted in significant (p=0.01) reductions in PM concentrations in the kitchen areas in all ten households which ranged from 24 to 87%, 20– 80% and 21– 62% for PM1, PM2.5 And PM10, respectively.

Qi et al (2019)[38] conducted a study in the **Sichuan Basin in southwest China** in eighteen biomass-burning rural households in a mountain village and three non-biomass-burning urban households. The study attempted to characterize the impacts of indoor combustion on PM2.5contamination. With significant solid fuel burning internal sources for cooking and heating in rural households, the highest concentration was found in the kitchen, with comparable levels in the living room and low levels in outdoor air. A generally opposite direction of indoor-outdoor exchange was found in the urban households, where pipelined natural gas was used for cooking and air conditioners for heating.

A study was done by **Deepthi et al (2019)**[39] in southern **Telangana** which dealt with the measurement of PM concentrations in rural households(N=40) under varied fuel and kitchen types and evaluation of the indoor air pollution (IAP) characteristics. The biomass households exhibited high levels of PM dosage (1181.4 to 5891.7 µg) against the LPG households (89.9 to 811.2 µg), the indoor kitchen types exhibited a maximumin tensification of 10.6 times than outdoor kitchens with the same fuel.

In a study in **rural Honduras** by **Young et al (2019)**[40] they assessed cross-sectional associations of 24-hour mean concentrations of personal and kitchen fine particulate matter (PM2.5) and stove type with blood pressure, among 147 women using traditional or cleaner-burning Justa stoves in Honduras. Traditional stove users had mean (standard deviation) personal and kitchen 24-hour PM2.5 concentrations of 126µg/m3 (77) and 360µg/m3 (374), while Justa stove users' exposures were 66µg/m3 (38) and 137µg/m3 (194), respectively. The average personal and kitchen PM2.5 concentrations were 48% and 62% lower, respectively, for Justa stove users compared to traditional stove users.

Tumwesige et al (2017)[41] conducted a study which monitored real-time PM2.5 and CO concentrations in 35 households in **Cameroon and Uganda** where biogas and firewood (or charcoal) were used. The 24 hour mean PM2.5 concentrations in households that used: (1) firewood and charcoal; (2) both firewood (mean 54% cooking time) and biogas (mean 46% cooking time); and (3) only biogas, were 449 mg/m3, 173 mg /m3 and 18 mg/m3 respectively. This exceeded the World Health Organisation guidelines when firewood and charcoal were used. Partially switching to biogas reduced CO exposure to below the World Health Organisation guidelines, but PM2.5 concentrations were only below the 24 hour recommended limits when households fully converted to biogas fuel.

12 biomass using households in **Janakpur, Nepal** was assessed by **Bartington et al (2017)**[42] as part of a subset of a larger study. Overall, 48-h average PM2.5 was 417.6 (SD 686.4)µg/m3 which exceeded WHO Indoor Air Quality Guidelines.

Results of a study by **Holmes et al (2014)**[43] in **Mexico** indicate that indoor air pollution has a strong dependence on cooking fuel, with gas stoves having hourly averaged median concentrations in the range of 134 to 157µg/m3 and biomass stoves 163 to 504µg/m3. The study measured continuous particulate matter (PM) concentrations in six homes.

In a crossectional study by **Pollard et al (2014)**[44] in **Peru** , 24-hour indoor PM concentrations were measured in 86 households. Median 24-hour indoor PM2.5 concentrations were 130 vs. 22 µg/m3 (all $p<0.001$) in rural vs. urban households. Having a chimney did not significantly reduce median concentrations in 24-hour indoor PM2.5 but having a thatched roof ($p=0.007$) was associated with higher 24-hour average PM concentrations.

Da Silva et al (2017)[45] assessed the pulmonary functions of 1402 people and quantified PM2.5 in their residence. He found an increased OR for cough, wheezing and dyspnoea in adults exposed to Indoor vs. biomass OR=2.93, 2.33, 2.59, respectively. PFT revealed both Non-Smoker-Biomass and Smoker-Gas individuals to have decreased FEV1 and FEV1/FVC. Prevalence of airway obstruction was 20% in both non-smoker-biomass and smoker-gas subjects.

Panigrahi A et al (2018)[26] conducted a community based cross sectional study in Odisha to determine the prevalence of chronic bronchitis and air flow obstruction, and its association with household fuel use. The sample was 1120 randomly selected never smoking women with age ranging between 18-49 years. They found that an increase in PM2.5 levels was associated with a significantly lower FEV1/ FVC.

A study was undertaken at Delhi during 2004-2005 by **Kumar R. et al**[46] to study the association between indoor air pollution and asthma in children. 3104 children aged 7-

15years from lower , middle- and upper-income groups were selected. Spirometry was done for these children and indoor SO2, NO2 and SPM pollutants were monitored in 25% of the houses. It was found that mean indoor SPM was significantly high in the households with asthmatic children and the differences were statistically significant.

In a study **by Awopeju, O. F et al**[47] on respiratory health of 415 women working as street cooks in Nigeria, who were assessed for respiratory symptoms and personal exposure of volatile organic compounds by samplers worn on their lapels. It was found that the benzene concentration was higher in samplers worn by the street cooks as compared to the controls. The adjusted odds ratio of respiratory symptoms were higher in street cooks with OR of cough- 4.4 and phlegm 3.9.

Pratali L et al (2012)[48] aimed to study the association of indoor biomass burning and pulmonary damage. For this78 participants from 32 houses were recruited from the Sherpa community of Nepal. They assessed the indoor $PM_{2.5}$ & PM_{10} levels as well as pulmonary functions. Peak concentrations of PM $_{2.5}$ of 592µg were found and 18 % of those over 40 years were found to have non-reversible bronchial obstruction.

3.3 Awareness regarding Pradhan Mantri Ujjwala Yojana

In a study by **Sharma et al (2019)**[49] on transition to LPG for cooking by two states(Raipur[510] and Ranchi[300]) in India , 126 samples were PMUY beneficiaries. The PMUY beneficiaries t can be seen that PMUY has significant positive impact on LPG Per Capita consumption and LPG share of monthly household energy in both Ranchi & Raipur. It shows that capital subsidy provided for LPG access is helping in LPG transition.

In a study by **Abhishek kar et al**[50] in rural **Karnataka (2019)** to assess cooking gas adoption and impact of Ujjwala programme, it was found that within 16 months of PMUY being launched in the district , PMUY beneficiaries in this region exceeded the number of general rural consumers. By the end of the available data window (December 2018), there were approximately 15,000 PMUY customers and 12,500 general customers in the database. The median monthly growth rate in PMUY customers was approximately six times that of the general customers over the same time period and twice that of the general customers in the pre-PMUY period. It was also seen that only 7% of PMUY consumers have purchased 4 or more cylinders. 24% of PMUY beneficiaries nationally purchased no refills during the first year. Low refill rates suggest that more effective incentives are needed for PMUY beneficiaries to become frequent LPG users.

In a survey based study by **Yadav et al (2020)**[51] on 187 women in Rajasthan which analyzed the impact of the PMUY scheme on the socio-economic status of women in the rural sector , they found the barriers to LPG refills to be - affordability (28%) , lack of home delivery(11%) , lack of awareness of LPG refill (9%) , easier access to biomass(28%) , fear of using LPG (18%) and delayed delivery of LPG(6%).

Chapter 4: METHODOLOGY

4.1 Study setting:

Jodhpur district is located in western part of Rajasthan. According to 2011 census, Jodhpur district has a population of 36,85,681. Jodhpur has a sex ratio of 915 females for every 1000 males[15]. Jodhpur district is included in the arid zone of the Rajasthan state[52]. The weather remains dry for the most part of the year. Over 70% of the population lives in villages or scattered settlements known as dhanis (Hamlets), where agriculture and animal husbandry are the primary occupations. The arid atmosphere facilitates the drying of wood and dung for use as cooking fuel.

The study was conducted in a rural area of Jodhpur which is 39 kms away from AIIMS Jodhpur. As per census 2011 [15], the population of Dhawa village is 4988 of which 2596 are males and 2392 are females. The study was carried out in Dhawa PHC due to COVID 19 restrictions as per public health guidelines for COVID 19 prevention[53].

4.2 Study design:

This study was a health facility based cross-sectional study among women visiting for any complaints to Dhawa PHC. This was supplemented with indoor air particulate matter concentration monitoring in households. The study was conducted from January 2020 to July 2021.

4.3 Study participants:

Women aged 15 years and above who visited Dhawa PHC were recruited for the study.

4.4 Sampling:

4.4.1 Sample size calculation:

Calculation of sample size was done considering 16.7% prevalence of chronic bronchitis as reported by Sukhsohale et al[21] with 20% relative error (absolute error of 3.34%) and 95% confidence interval.

$$N = \frac{\left(z_{1-\alpha/2}\right)^2 p(1-p)}{d^2}$$

Where ' $z_{1-\alpha/2}$ ' = 1.96 as it is standard normal variate at 5% type 1 error,

'p'= 16.7% is the prevalence of chronic bronchitis

And 'd' is the relative precision 20% of p

$$N = \frac{[(1.96x1.96)16.7x83.3]}{3.34x3.34} = 479$$

Substituting all these in the formula the sample size was found to be 479.

4.4.2 Sampling technique:

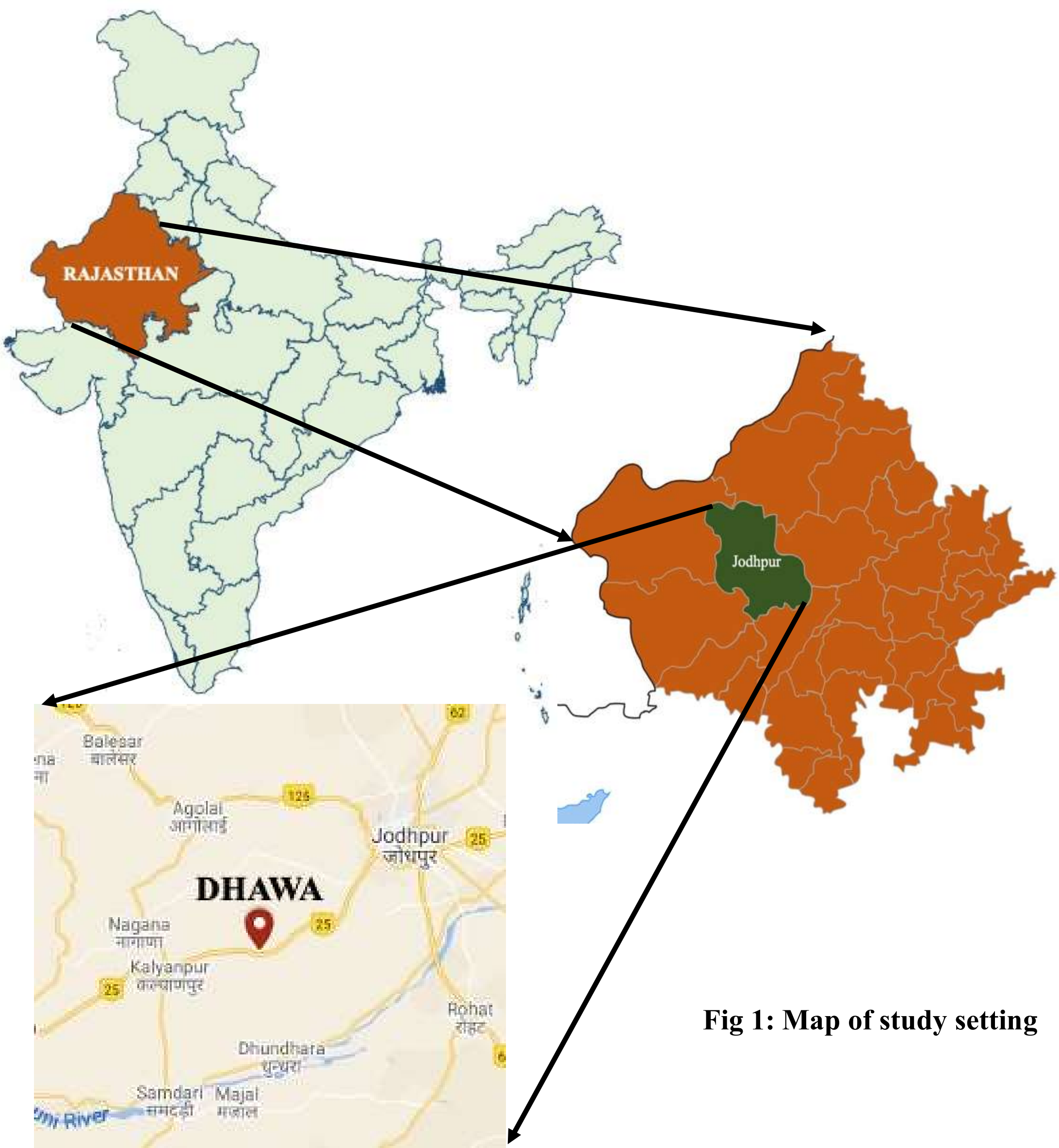


Fig 1: Map of study setting

List of all the blocks of Jodhpur were procured from the office of Municipal Corporation of Jodhpur. This enlisted the blocks – Bhopalgarh, Balesar, Bilara, Bap, Bawari, Luni, Osian, Phalodi, Mandore and Shergarh. The block Luni was selected from these by simple random sampling using Microsoft excel 2016. From Luni block, by multistage random sampling, the village Dhawa (population of 4,988) [census 2011] was selected[15].

Participants were recruited from the outpatients at PHC Dhawa for study. A convenience sampling approach was adopted. This was done because house to house survey and selection of woman according to Kish grid planned initially was not possible due to the nationwide lock down and the imposed public health measures[54]. A total of 360 people were recruited from outpatients at the PHC and 120 people were recruited from households that were approached for particulate matter monitoring during time period when peak of COVID 19 pandemic subsided and there was relaxation of government guidelines.

The households for PM monitoring were chosen via systematic random selection. Every fourth house was identified from the starting point of a street. In case the 4th house was closed, or the residents declined permission to place the monitor, the house next door was approached. The air quality in the selected residences was monitored for a 24-hour period. The total number of houses planned for air quality monitoring was 120, almost a fourth of the main sample size of women planned to be recruited.

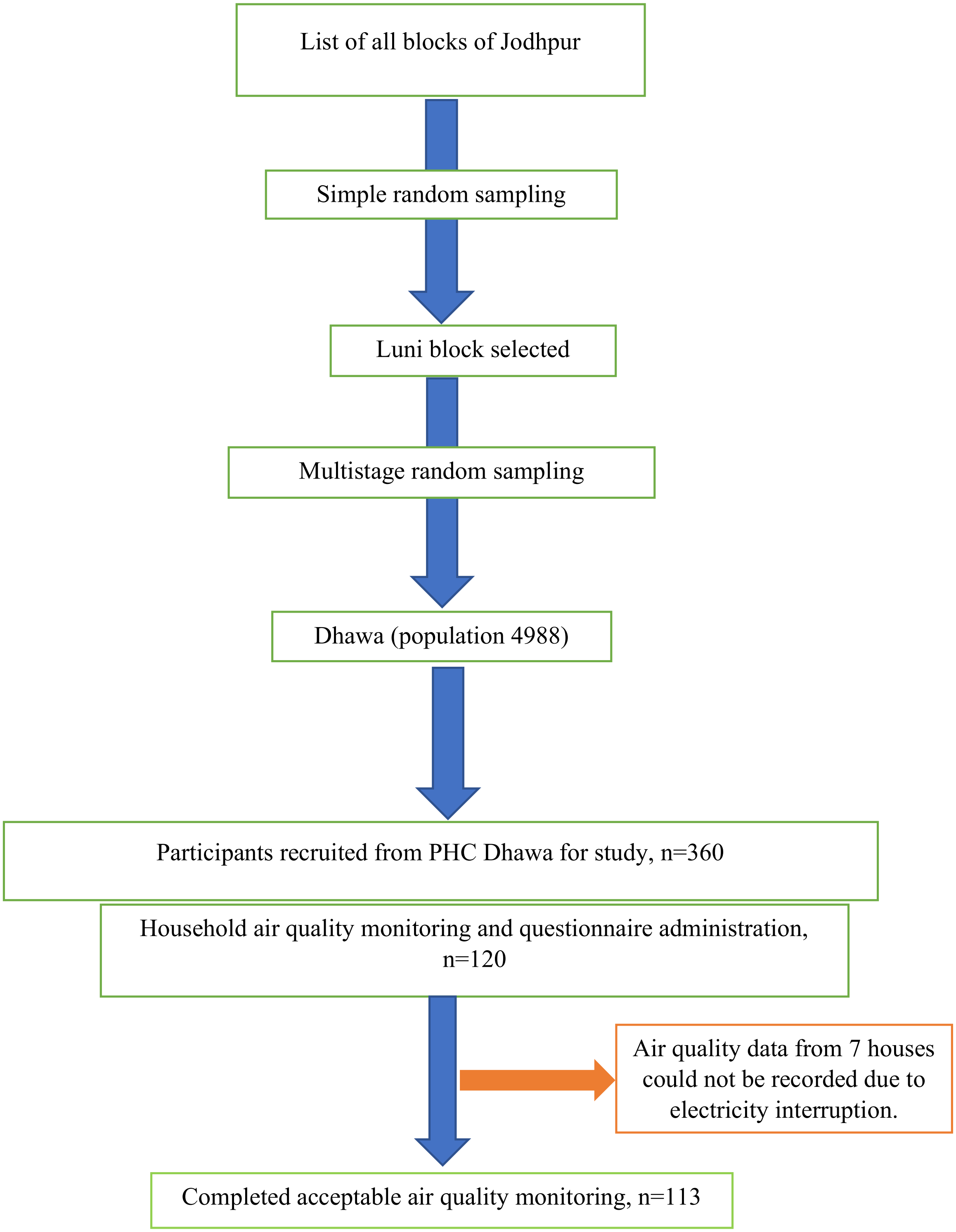


Fig 2: Schematic representation of sampling technique

4.5 Data collection:

The study was conducted from Jan 2020 to July 2021. Pilot study was done in January and February of 2020. The data collection from field area was interrupted from March due to the lockdown announced by the government from 22 March 2020[53]. The questionnaire was thus administered to women outpatients at PHC Dhawa after modification of methodology.

Lung function testing of participants was initially planned to be carried out in the participants. In view of the potential risk of aerosol generation by cough during the procedure and associated possible COVID 19 transmission to persons in and around the area , it was recommended to restrict spirometry to only those whom it was absolutely necessary[55,56]. Therefore, it was decided to be modify the methodology by excluding spirometry.

Air quality monitoring of kitchens in households were done from January 2021.

The total number of houses planned for air quality monitoring was 120, almost a fourth of the main sample size of women planned to be recruited. Every fourth house was identified from the starting point of a street by systematic random sampling. In case the identified house was closed or if the residents declined permission to place the monitor, the house next door was approached. The air quality in the selected residences was monitored for a 24-hour period.

Households were categorized into 3 groups -

"LPG stove using" households used exclusively Liquefied Petroleum Gas (LPG) for cooking"; "mixed fuel: household used a combination of fuel (LPG and solid biomass) for cooking" and "traditional mud stove using": household used exclusively biomass fuel for cooking".

Kitchen structures varied across the houses visited for particulate matter measurement. They were split into three categories: Inside, Outside kitchen and Open . The instruments were installed in the kitchen. For 24 hours, the samplers were positioned near the stoves in an obstruction-free location at a typical person's height. Before identifying and placing in other residences, the data stored in the device (on SD card) was extracted at weekly intervals (on Saturdays).

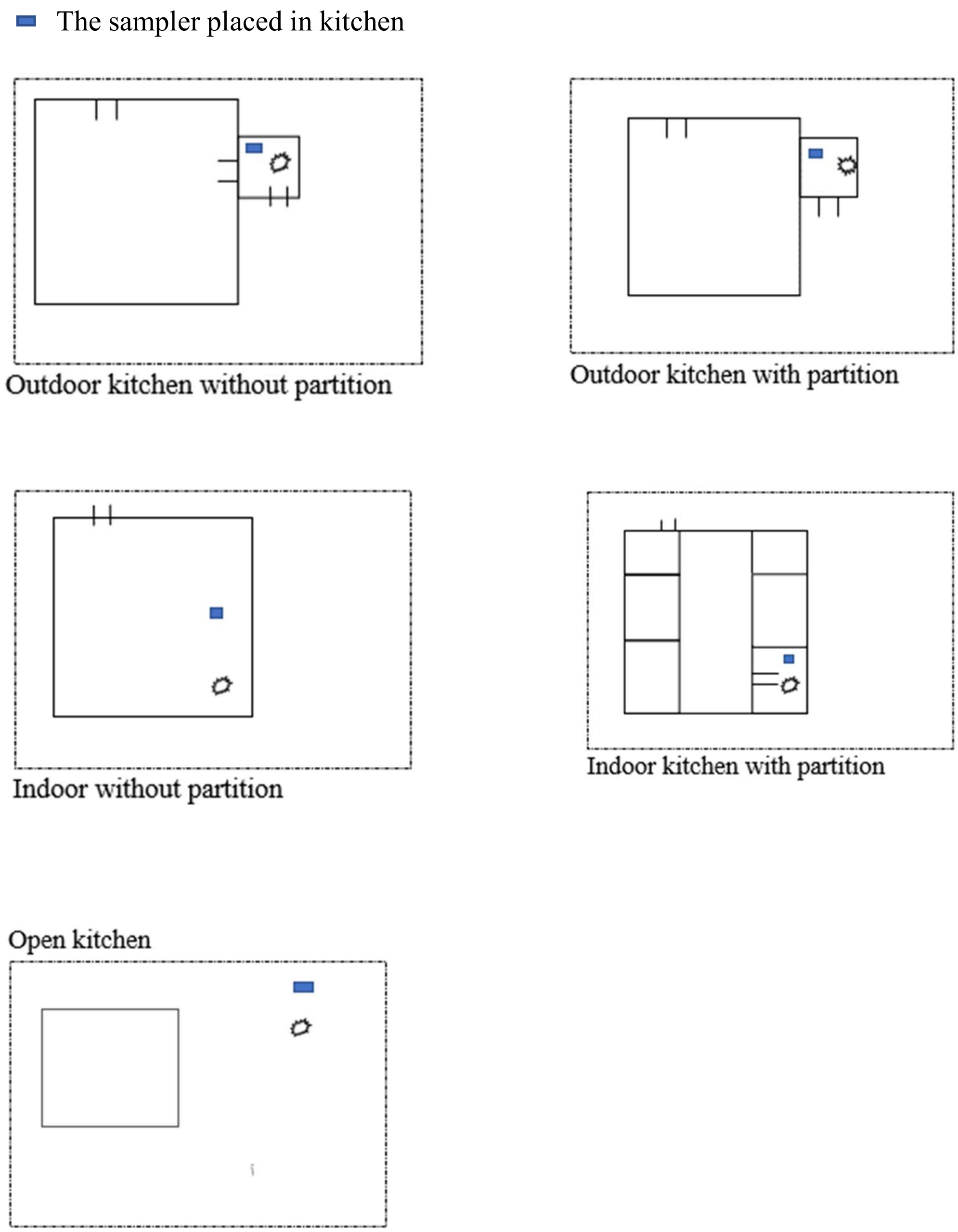


Fig 3: Pictorial representation of cooking locations in households and placing of sampler for monitoring.

Operational definition:

Acute respiratory infections (ARIs) are classified as upper respiratory tract infections or lower respiratory tract infections.

History of nasal discharge, cough, fever, sore throat, breathing difficulty, any discharge from ear alone or in combination was used in the recognition of an episode of ARI.

An absence of symptoms for three days or more was the criterion used to differentiate one episode from another[57].

4.6 Study tools:

Following tools were used for data collection

1. **A semi structured questionnaire**: An interview-based questionnaire was used for data collection with a questionnaire adapted from World Bank indoor air pollution survey(58). The questionnaire was translated to Hindi and back translation was also done to ensure appropriateness.

The questionnaire was pilot tested in an urban block of Jodhpur, and it was observed that the number of houses utilising traditional mud stoves were less. Only two of the 15 families studied in the pilot research utilised a mud stove. All the other houses used LPG stoves for cooking.

After revisions in the questionnaire, piloting was done in a rural village of Jodhpur. All 20 households had traditional mud stoves. LPG stoves were found to be used in 13 of the households.

It included-

a. Sociodemographic details
b. Household characteristics
c. Stove and fuel use
d. Health details of participants
e. PMUY awareness

f. Children characteristics

g. Pictorial representation of kitchen and stove

2. **Air quality monitoring device**

Air samples were captured using a real time air quality monitor. The device measures real time particulate matter concentrations- PM_{1}, $PM_{2.5}$ & PM_{10} µg/m^3. It has PM and Temperature sensor inside which captures the real time data. Sensor inside the device works on Laser Scattering Principle. The PM data collected at 1min intervals was saved on a microSD card which was placed within device. The device had been scientifically validated and calibrated against Federal Equivalent Method (FEM) grade equipment.

Prior to each monitoring, the instrument was subjected to the required background and flow tests. The instrument was kept at an obstruction free spot for a period of 24 hours in each household. It was kept in an obstruction-free location for a duration of 24 hours. At the end of 24 hours the device was collected from the site and placed in the site/kitchen of a different/next house. The microSD card was extracted from the machine at the end of the week, the logged data was then copied.

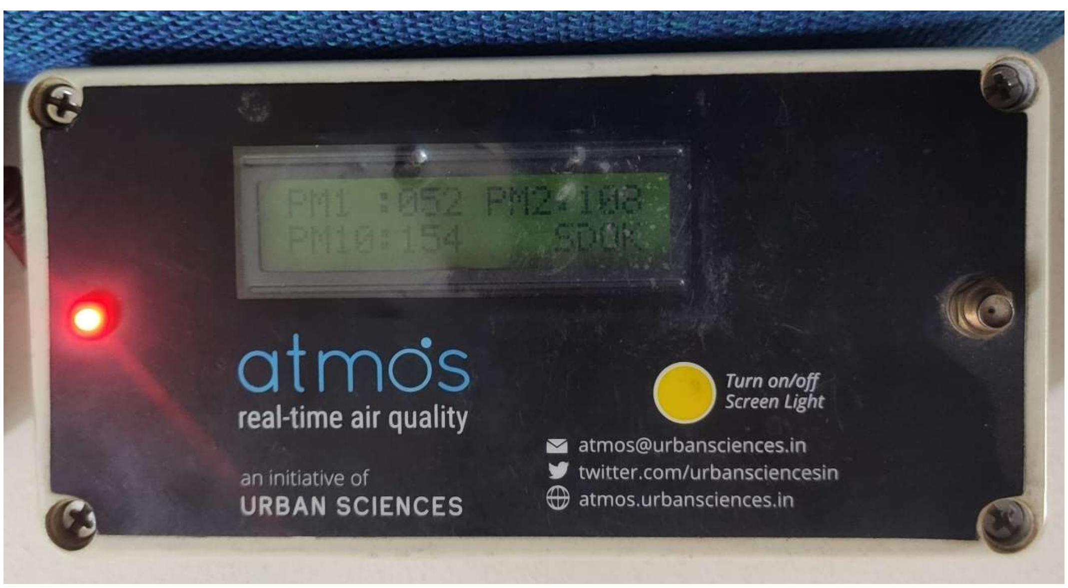


Fig 4: Real time air quality monitor

4.7 Outcome measures:

1. Proportion of women with respiratory morbidities among different type of fuel users, and the association of respiratory morbidities and biomass fuel.

2. Prevalence of acute respiratory tract infection episodes among under five and biomass fuel.

3. Hourly PM1, PM2.5 and PM10 values among households using different types of fuel.

4. Awareness regarding Pradhan Mantri Ujjwala Yojana and adoption of LPG.

Fig 5: Data collection from household

Fig 6: Traditional mud stove outside kitchen

Fig 7: Exclusive LPG stove kitchen with monitoring device

4.8 Statistical analysis:

The collected data was entered in Microsoft excel sheets of Office version 2019. This was analysed using version 23 of the Statistical Package for Social Sciences (SPSS) [IBM Corp]. Data cleaning was done manually. Descriptive data were described with mean, median, standard deviation and Interquartile ranges. Univariate analysis was done using Chi square test, Fischer's exact test and Kruskal wallis test were the tests of statistical significance that were applied. Regression was also done. All the tests of significance was applied at 95% confidence interval.

4.9 Ethical consideration

Ethical approval was obtained from Institutional Ethical Committee of AIIMS Jodhpur vide their letter no AIIMS/IEC/2019-20/978 dated 01/01/2020.

The study's purpose was explained to all participants. Consent was taken from all the participants after inclusion into the study. Before the questionnaire was administered, all of the women participants were given a participant information sheet and told about their role in the study. They were assured that the information gathered about them would be kept completely confidential, and that they may withdraw from the study at any time. All the study participants who were having respiratory symptoms were given appropriate treatment or referral services as and when considered to be necessary throughout the study period.

Chapter 5: RESULTS

In the present study, 480 women were recruited, 360 women through interviews from those who visited the Dhawa CRHA and remaining 120 from the houses which were approached for particulate matter assessment. All the children in the households of the recruited women were also enrolled for study.

5.1 Sociodemographic details of participants of the study

The women ranged in age from 15 to 82 years. The mean age of the study participants was 36 ± 14.71 years. The median (range) age of the women of the study was 30 (15 to 82) years. The median age of the women using LPG stove was 35 (16 to 82) years which is higher as compared to that of biomass using women which was 30 (15 to 75) years. Women aged 30 to 39 years old made up the majority (31.6%) of LPG consumers, whereas women aged 20 to 29 years old made up the majority (41%) of biomass users.

The median years of schooling of the participants was observed to be 4 and was found to be same for both biomass and LPG stove users.

Majority (68%) of the participants had completed primary education which was also observed among LPG users (80%) and biomass users (65%).

Only 4% of the women in the study were head of households; and this was similar for both LPG users (2.1%) and biomass users (4.4%).

Families that used biomass had an income ranging from Rs 1500 to Rs 40000, while those who utilised LPG had an income ranging from Rs 3000 to Rs 40000. The majority of LPG stove users (30.5%) have a family income of Rs 20,000 or more, while the

majority of biomass stove users (37.9%) have a family income of less than Rs 10,000. The socioeconomic status of study participants was determined by using modified BG Prasad scale for the base year 2019. Women from the upper middle class constituted 40% of the study population. LPG users were primarily upper class (41%), but biomass users were mostly upper-middle-class (48.4%). Only 18 (3.8 %) of the women in the study came from low-income families.

Table 1: Sociodemographic details of women participants, n=480

Demographic details	LPG user n=95 (%)	Biomass user n=385 (%)	Total	p value
Age in years, Median	35 (16 – 82)	30 (15 – 75)	30 (15-82)	0.004[!]
Age in years, Mean ± SD	39.53 ±	35.89 ± 14.34	36.61 ±	0.051[!]
Age group wise in years	n (%)	n (%)		
15-19	3 (3.2)	11 (2.9)	14 (2.9)	0.241
20-29	25 (26.3)	158 (41.0)	183 (38.1)	
30-39	30 (31.6)	91 (23.6)	121 (25.2)	
40-49	4 (4.2)	23 (6.0)	27 (5.6)	
50-59	20 (21.1)	54 (14.0)	74 (15.4)	
60-69	10 (10.5)	41 (10.6)	51 (10.6)	
70-89	3 (3.2)	7 (11.8)	10 (2.1)	
Educational status	n (%)	n (%)	n=480	
Years of schooling, Mean ±	5.21 ± 10.13	5.47 ± 7.35	5.42 ±	0.012[!]
Illiterate	7 (7.4)	21 (5.5)	28 (5.8)	0.011*
Primary (1 to 5)	76 (80.0)	250 (64.9)	326 (67.9)	
Middle (6 to 8)	6 (6.3)	73 (19.0)	79 (16.5)	
Secondary (9 to 10)	5 (5.3)	33 (8.6)	38 (7.9)	
Senior secondary and higher	1 (1.1)	8 (2.1)	9 (1.9)	
Gender of Head of	n (%)	n (%)		
Male	93 (97.9)	368 (95.6)	461 (96.0)	0.391*
Female	2 (2.1)	17 (4.4)	19 (4.0)	0.451
Family Income				
Monthly income in Rs,	15000 (3000	10000 (1500-		
Family Monthly income	n (%)	n (%)		
Rs 20210 to Rs 40429	29 (30.5)	12 (3.1)	41(8.5)	0.001*
Rs 15160 to Rs 20209	17 (17.9)	33 (8.6)	50(10.4)	
Rs 10110 to Rs 15159	18 (18.9)	85 (22.1)	103(21.5)	
Rs 6060 to Rs 10109	8 (8.4)	146 (37.9)	154(32.1)	
Rs 2021 to Rs 6059	23 (24.2)	99 (25.7)	122(25.4)	
≤Rs2020	0	10 (2.6)	10(2.1)	
Socioeconomic status by Modified BG Prasad Scale				
I (Upper class)	46(48.4)	61(15.8)	107(22.3)	0.001*

II (Upper middle)	34(35.8)	158(41.0)	192(40.0)	
III (Lower middle)	5(5.3)	90(23.4)	95(19.8)	
IV (Upper lower)	8(8.4)	60(15.6)	68(14.2)	
V (Lower)	2(2.1)	16(4.2)	18(3.8)	
! Mann Whitney u test * Fischer exact test				

5.2 Sociodemographic details of under-five child participants of study

The study enlisted 272 children. Children in LPG and biomass-using families had median(range) ages of 2.47 years (4 months to 5 years) and 2.49 years (1 month to 5 years), respectively. Males constituted 54.8 % of all children, while females accounted for 45.2 %.

Table 2: Sociodemographic details of under five children, n=272

Participant characteristics	LPG user n=40	Biomass user n=232	Total n=272	p value
Age in years, median (Range)	2.47(4m – 5yrs)	2.49(1m – 5yrs)	2.4(0 - 5 years)	0.026!
Gender of children				
Male	29 (72.5)	120 (51.7)	149 (54.8)	0.015#
Female	11 (27.5)	112 (48.3)	13 (45.2)	
Age of child				
0 to 11months	2 (5.0)	25 (10.8)	27 (9.9)	0.496
12 to 23months	8 (20.0)	42 (18.1)	50 (18.4)	
24 to 35months	14 (35.0)	70 (30.2)	84 (30.9)	
36 to 47 months	10 (25.0)	41 (17.7)	51 (18.8)	
48 to 60months	6 (15.0)	54 (23.3)	60 (22.1)	
Socioeconomic status by Modified BG Prasad Scale				
I (Upper class)	12 (30.0)	18 (7.8)	30 (11.0)	0.001*
II (Upper	11 (27.5)	97 (41.8)	108 (39.7)	
III (Lower	4 (10.0)	76 (32.8)	80 (29.4)	
IV (Upper	11 (22.9)	37 (15.9)	48 (17.6)	
V (Lower Class)	2 (5.0)	4 (1.7)	6 (2.2)	
! Mann Whitney u test # Chi square test * Fischer's exact test				

Among LPG users, male children accounted for 72.5 %, whereas male (54.8 %) and female (45.2 %) children were found in nearly equal proportions in biomass-using households. The majority of children among LPG user (35%) and biomass user (30%) groups were between the ages 2 to 3.

Nearly 3/5th of children from LPG users belong to the upper class/higher socioeconomic status while 50% of children belong to lower classes among biomass users (lower middle ,upper lower and lower /per capita income less than Rs1401).

Concrete roofs (63.1%) and flooring (87.1%) were found in the majority of houses. Compared to biomass users, who had just 57.9% of roofs and 84.4 % of walls built of concrete, LPG users had a much higher proportion of houses with concrete roofs (84.2%) and floors (97.9%). The same was true of stone and brick walls, with the majority (90.2%) of houses constructed of them and a larger percentage (93.7%) of LPG user house walls made of brick than biomass users (89.4 %).

Houses having kitchen inside house with partition were in greater proportions among LPG users (68.4%) while biomass users had a greater percentage (41.3%) houses with kitchen that were outside with partition. Open kitchen was observed only among biomass users (6.5%).

Table 3: Distribution of household characteristics among study participants, n=480

	LPG user n=95	**Biomass user n=385**	**Total**	**p value**
House Roof material	n (%)	n (%)	n (%)	
Concrete	80 (84.2)	223 (57.9)	303(63.1)	0.001#
Corrugate iron	3 (3.2)	77 (20.0)	80 (16.7)	
Thatched	3 (3.2)	32 (8.3)	35 (7.3)	
Stone and Brick	9 (9.4)	23 (6.0)	32 (6.7)	
Tile	0	30 (7.8)	30 (6.3)	
House Wall material	n (%)	n (%)	n (%)	
Concrete	6 (6.3)	39 (10.1)	45 (9.4)	0.619
Stone and Brick	89 (93.7)	344 (89.4)	433(90.2)	
Mud	0	2 (0.5)	2 (0.4)	
House Floor material	n (%)	n (%)	n (%)	
Concrete	93 (97.9)	325 (84.4)	418(87.1)	0.001#
Stone and Brick	2 (2.1)	10 (2.6)	12 (2.5)	
Mud	0	50 (13)	50 (10.4)	

Location of Kitchen	n (%)	n (%)	n (%)	
Inside with Partition	65 (68.4)	117 (30.4)	182(37.9)	0.001*
Outside With Partition	17 (17.9)	159 (41.3)	176(36.7)	
Outside Without Partition	2 (2.1)	26 (6.8)	28 (5.8)	
Inside Without Partition	10 (10.5)	18 (4.7)	28 (5.8)	
Separate	1 (1.1)	40 (10.4)	41 (8.5)	
Open	0	25 (6.5)	25 (5.2)	
Walls in Kitchen, n=455$	n=95	n=360	n=455	
1	0	26 (7.2)	26 (5.7)	0.001#
2	5 (5.3)	36 (10.0)	41 (9.0)	
3	5 (5.3)	103 (28.5)	108(23.7)	
4	85 (89.5)	195 (54.0)	280(61.4)	
Windows in kitchen, n=455$	n=95	n=360	n=455	
0	18 (18.9)	104 (28.9)	122(26.8)	0.118
1	75 (78.9)	249 (69.2)	324(71.2)	
2	2(2.1)	7(1.9)	9 (2.0)	
Doors in kitchen, n=455$	n=95	n=360	n=455	
0	7 (7.4)	163 (45.3)	170(37.4)	0.001*
1	82 (86.3)	193 (53.6)	275(60.4)	
2	6 (6.3)	4 (1.1)	10 (2.2)	
Crossventilation in kitchen,	n = 85	n = 195	n = 280	
Yes	46 (54.1)	135 (69.2)	181(64.6)	0.001#
No	28 (32.9)	58 (29.7)	86 (30.7)	
Not applicable!	11 (12.9)	2 (1.0)	13 (4.6)	
Kitchen Roof material	n=95	n=360	n=455	
Concrete	65(68.4)	180 (46.8)	245(51.0)	0.002@
Corrugate iron	19 (20.0)	94 (24.4)	113(23.5)	
Thatched	0	48 (12.5)	48 (10.0)	
Stone	9 (9.5)	30 (7.8)	3 (8.1)	
Tile	2 (2.1)	9 (2.3)	11 (2.3)	
Kitchen Wall material	n=95	n=360	n=455	
Concrete	7 (7.4)	37 (9.6)	44 (9.2)	0.828
Corrugate iron	0	4 (1)	4 (0.8)	
Stone and Brick	88 (92.6)	316(82.1)	404(84.2)	
Wood	0	4 (1.0)	4 (0.8)	
Kitchen Floor material	n=95	n=360	n=455	
Concrete	88 (92.6)	241 (62.6)	329(68.5)	5.826
Stone and Brick	4 (4.2)	9 (2.3)	13 (2.7)	
Mud	3 (3.2)	111 (28.8)	114(23.8)	
Total family size of household	n=95	n=385	n=480	
1 to 3 people	12 (12.6)	35 (9.1)	47 (9.8)	

4 to 5 people	30 (31.6)	134 (34.8)	164(34.2)	0.641
6 to 7 people	30 (31.6)	111 (28.8)	141(29.4)	
8 to 9 people	15 (15.8)	57 (14.8)	72 (15.0)	
>=10 people	8 (8.4)	48 (12.5)	56 (11.7)	
Number of stories in house	n=95	n=385	n=480	
1	75 (78.9)	366 (95.1)	441(91.9)	0.001#
2	20 (21.1)	19 (4.9)	39 (8.1)	
Overcrowding (person per room)	n=95	n=385	n=480	
Yes	75 (78.9)	275 (71.4)	350(72.9)	0.157
No	20(21.1)	110(28.6)	130(27.1)	
Toilet facility	n=95	n=385	n=480	
Modern toilet	90 (94.7)	321 (83.4)	411(85.6)	0.008#
Open defecation	5 (5.3)	64 (16.6)	69 (14.4)	

$ Open kitchens excluded
# Chi square statistic
* Fischer's exact test
@ Yate's chi square
! Not having atleast one window and one door

LPG users had a significantly higher (89.5%) proportion of kitchens with 4 walls as compared to biomass users (54%). Majority (78.9%) of the LPG users had at least one window in the kitchen. Among biomass users 69.2% had at least one window in the kitchen but there were 28.9% kitchens among them were there was no window. Among biomass 53.6% had one door in the kitchen but 86.3% LPG users had at least one door in the kitchen. Majority (52.6%) of LPG users had cross ventilation within the kitchen while only 38.1% of biomass users had cross ventilation.

Among LPG users 68.4% kitchens had roofs made of concrete which was significantly (p=0.002) higher than that in biomass user kitchens (46.8%). Thatched roofs for kitchen were found only among biomass users (12.5%). Majority of LPG users had kitchen walls (92.6%) made of stone and brick and floors (92.6%) made of concrete.

Majority (91.9%) of households had at least one story in their houses. A significantly (p=0.001) higher proportion (21.1%) of houses among LPG users have 2 storied households.

Around 60% of all households had a total family size of 4 to 7 people and which is also reflected among LPG and biomass users. Overcrowding was equally observed among LPG users (78.9%) and biomass users (71.4%).

Nearly 1/5th of biomass users reported to practice open defecation while only 5.3% off LPG users practiced it.

Table 4: Distribution of Pradhan Mantri Ujjwala Yojana (PMUY) services among participants, n=480

	LPG user n=95 (%)	Biomass user n=385 (%)	Total n=480 (%)	p value
Awareness about PMUY	40 (42.1)	218 (56.6)	258 (53.8)	0.011#
Applied for PMUY	36 (37.9)	183 (47.5)	219 (45.6)	0.091#
Received cylinder for PMUY	36 (37.9)	175 (45.5)	211 (44.0)	0.184#
#Chi square statistic				

A higher proportion of biomass users were aware of PMUY (56.6%), had applied for it (45.6%) and received it (44%) as compared to LPG user.

Table 5: Description of participant cooking behaviours, n=480

	LPG user n=95 (%)	Biomass user n=385 (%)
Primary cook	95 (100)	361 (93.76)
Not primary cook	0	24 (6.23)
Years of cooking, n=480		
Mean ± SD	26.91 ± 15.68	21.46 ± 15.02
Median (range)	23 (2-72)	21.46 (0 - 60)
Days in a month spent cooking		
0 to 9 days	9 (9.5)	24 (6.2)
10-19 days	3 (3.2)	28 (7.3)
20 to 29 days	4 (4.2)	36 (9.4)
30 days	79 (83.2)	297 (77.1)
Hours spent in a day cooking		
Median (range)	2 (1-3)	1 (1-3)
0 to 1 hr	17 (17.9)	270 (70.1)
1.1 to 2 hrs	63 (66.3)	89 (23.1)
2.1 to 3 hrs	6 (6.3)	20 (5.2)
Cooking frequency per day		
0	1 (1.1)	63 (16.4)

1	22 (23.2)	139 (36.1)
2	3 (3.2)	130 (33.8)
3	27 (28.4)	51 (13.2)
≥4	36 (37.8)	2 (0.5)

Women started cooking on traditional mud stoves at an average age of 14.07 ± 3.42 years. Cooking takes an average of 1 hour for women using a typical mud stove.

There were women (16.4%) who said they didn't cook at all with biomass fuel on a day among the participants who lived in residences that used biomass fuel. This might be due to the fact that they are employing a traditional mud stove as a supplementary fuel source that is not utilised on a regular basis, and that some of them are not the household's primary cook.

5.3 Stove use preferences among women participants of household

Among the mixed fuel users, the households where further divided to those using LPG as a primary stove (which used LPG stove more for the total duration of cooking) and those that used it as a secondary stove.

Table 6: Distribution of stoves in the households of participants, n=480

Stove use Pattern	**n=480(%)**
Mixed stove user	
Primary LPG with secondary Mud Stove	156 (32.5)
Primary mud stove with secondary LPG	207 (43.12)
Only LPG	95 (19.7)
Only traditional mud Stove	22 (4.58)

Only 4% of participants used mud stove exclusively while nearly 1/5th of the participants was exclusively using LPG stove.

Higher proportion (43.1%) of participants used LPG as a secondary stove among mixed fuel users as compared to primary LPG stove users (32.5%).

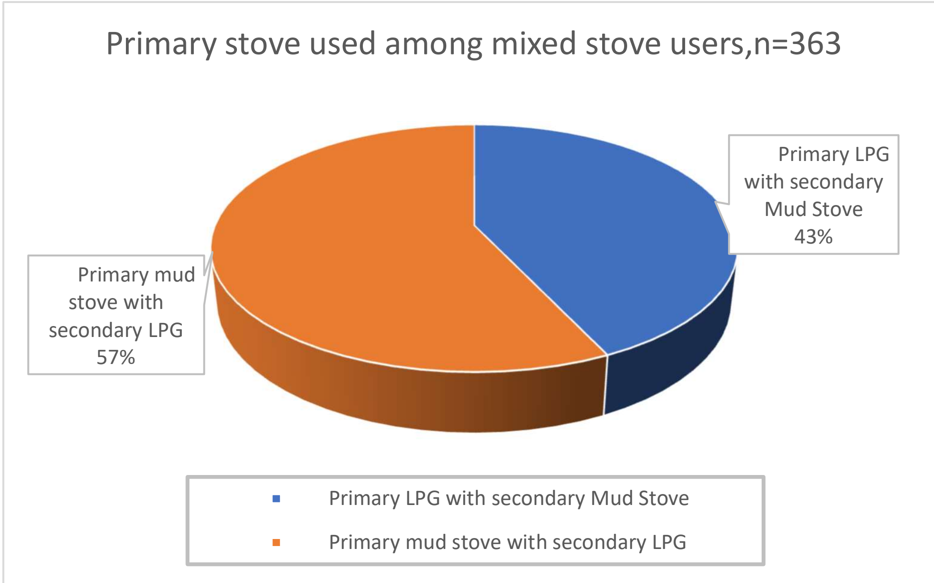


Fig 8: Type of primary stove used in the households of mixed stove using participants, n=363

Among the mixed fuel users only 43% reported to use LPG as a primary fuel. Majority (57%) reported using biomass as primary fuel.

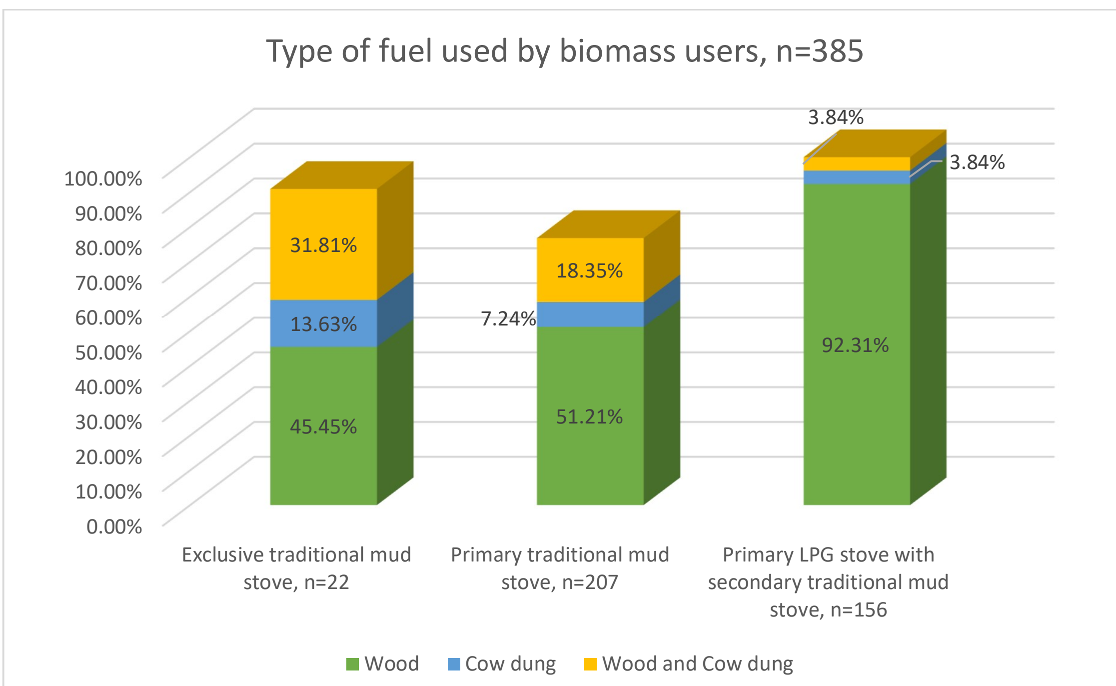


Fig 9: Bar chart of types of fuel used by traditional mud stove using households, n=385

Majority of the biomass users among both primary (72.48%) and secondary (92.31%) traditional mud stove users were using wood as their biomass fuel. A higher proportion of primary traditional mud stove users used cow dung (7.86%) and wood with cow dung (19.65%) as compared to secondary traditional mud stove users.

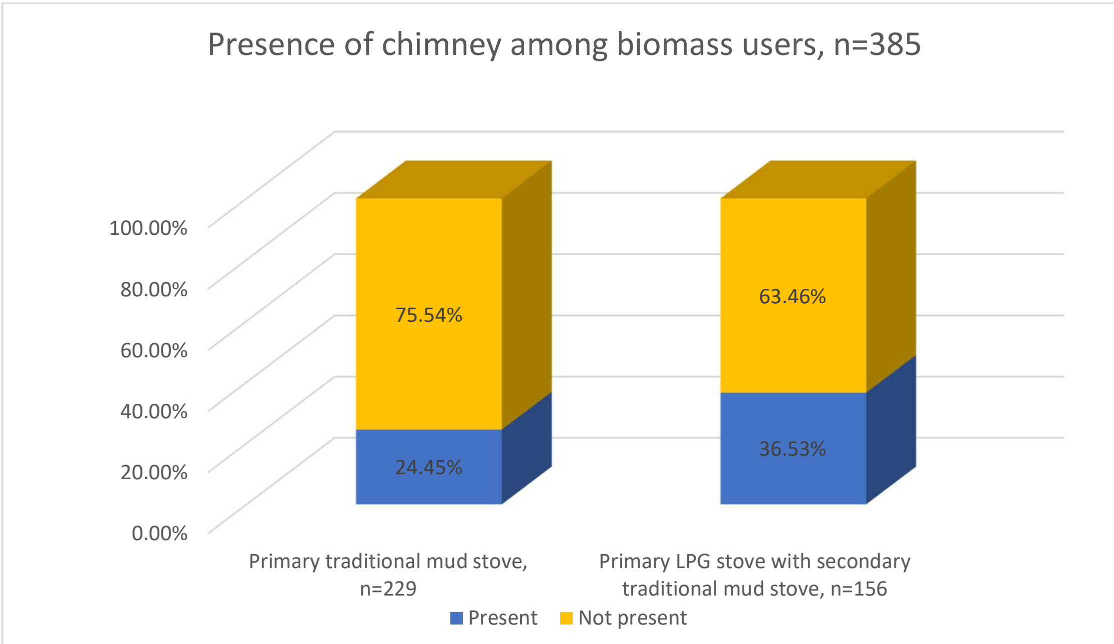


Fig 10: Bar chart for traditional mud stove using households with chimney, n=385

A larger proportion of secondary traditional mud stove (36.53%) users reported having chimney in their kitchens as compared to primary traditional mud stove users (24.45%).

Table 7: Distribution of chimney among households of study participants, n=152

Chimney	**LPG n=39 (%)**	**Primary mud stove user n=56 (%)**	**Secondary mud stove user n=57 (%)**
Open	16 (16.8)	42 (75.0)	34 (59.6)
Canopy	4 (4.2)	12 (21.4)	21 (36.8)
Electric exhaust	19 (20.0)	2 (3.5)	2 (2.5)

Of the households having primary traditional mud stoves only 56 households had chimney. Open chimneys accounted for 75% of the total, with electric exhaust accounting for only 3.57%. The reported open chimneys were actually eave spaces which provided minimal ventilation. As for households which used traditional mud stoves as secondary stoves, 92.31% of them used wood as biomass fuel for burning. The number/proportion of households using exclusive cow dung or a combination of wood with cow dung were the same . Among them 57 households had chimneys, majority of which were open (59.64%).

Majority of the participants both primary(75%) and secondary(59.64%) traditional mud stove users reported having open chimneys. Only a very small proportion among both primary(3.57%) and secondary(2.52%) traditional mud stove users had electric exhaust chimneys.

None of the participants reported that they used biomass fuel to remain warm in the winter and avoid being bitten by mosquitoes or bugs.

Seasonal variation in use of stoves

The seasons in Rajasthan are divided based on crop cultivation as Kharif and Rabi. Kharif season from June to October and Rabi season from October to April/May. Based on this Period 1 is defined as months from June to October and Period 2 from October to May. None of the participants reported a difference in stove choice based on seasons.

5.4 Health Outcomes

The total number of women participants who reported to be visiting a doctor in the last 2 weeks from time of getting recruited are 103. The median age of these women participants is 30.01(25) years. Mean monthly per capita income of these women was Rs 1872.93 ± 1394.96).

Table 8: Distribution of health outcomes of women participants, n=480

	LPG user n=95	**Biomass user n=385**	**Total n=480**	**p value**
Physician visit in last 2 weeks	24 (25.3)	79 (20.5)	103 (21.5)	0.313
Reason for visit				
Wheezing	0	21 (5.4)	21 (4.4)	0.107
Shortness of breath	4 (4.2)	6 (1.6)	10 (2.1)	
Tightness of chest	0	6 (1.6)	6 (1.3)	
Other	91 (95.8)	352 (91.4)	443 (92.2)	

Reason for visit				
Respiratory complaint	4 (4.2)	33 (8.6)	37 (7.7)	0.154
Other	91 (95.8)	352 (91.4)	443 (92.3)	
Ever experienced difficulty breathing due to smoke while cooking in kitchen	39 (41.1)	99 (25.7)	138 (28.7)	0.003*
Experienced trouble breathing in last 6 months				
Yes	22 (23.2)	58 (15.1)	80 (16.7)	0.058
No	73 (76.8)	327 (84.9)	400 (83.3)	
Ever experienced cough due to smoke while cooking in kitchen	41 (43.2)	105 (27.3)	146 (30.4)	0.003*
*Chi square test				

Among LPG users 4.2% reported that they had visited doctor in the past 2 weeks for complaints of wheezing and 5.5% of biomass users for the same. Majority of LPG users (95.8%) and biomass users (79.5%) visited doctor for other complaints.

Majority of the LPG users (23.2%) reported having experienced trouble breathing in last 6 months but only 15.1% biomass users had reported the same.

Among LPG users 43.2% reported cough due to smoke while cooking in kitchen and 41% reported difficulty breathing due to smoke while cooking in kitchen. Biomass users had a significantly lower percentage of individuals with cough (27.3%) and trouble breathing due to smoke while cooking in kitchen (25.7%).

Table 9: Distribution of health outcomes of under-five children, n=272

	LPG user n=40 (%)	Biomass user n=232 (%)	Total n=272 (%)	p value
Children with Acute respiratory illness episodes in the last 3 months				
No ARI episodes	31 (77.5)	129 (55.6)	160 (58.8)	0.009*
≥1 ARI episodes	9 (22.5)	103 (44.4)	112 (41.2)	
Children with Acute respiratory illness episodes in the last 3 months				
0	31 (77.5)	129 (55.6)	160 (58.8)	0.096
1	7 (17.5)	87 (37.5)	94 (34.6)	
2	1 (2.5)	15 (6.5)	16 (5.9)	
3	1 (2.5)	1 (0.4)	2 (0.7)	
Children with Acute respiratory illness episodes in the last 3 months				
Male	6 (66.7)	64 (62.1)	70 (62.5)	1.000
Female	3 (33.3)	39 (37.9)	42 (37.9)	
Immunization status of child, n=272				
Partially immunized	5 (12.5)	21 (9.1)	26 (9.6)	0.558
Completely immunized	35 (87.5)	211 (90.9)	246 (90.4)	
Partially immunized, n=26				
0 to 11months (<1yr)	1 (20.0)	1 (4.8)	2 (7.7)	--------
12 to 23months	0	4 (19.0)	4 (15.4)	
24 to 35months	0	7 (33.3)	7 (26.9)	
36 to 47 months	2 (40.0)	4 (19.0)	6 (23.1)	
48 to 60months	2 (40.0)	5(23.8)	7 (26.9)	
Completely immunized, n=246				
0 to 11months (<1yr)	1 (2.9)	24 (11.4)	25 (10.2)	0.199
12 to 23months	8 (22.9)	38 (18.0)	46 (18.7)	
24 to 35months	14 (40.0)	63 (29.9)	77 (31.3)	
36 to 47 months	8 (22.9)	37 (17.5)	45 (18.3)	
48 to 60months	4 (11.4)	49 (23.2)	53 (21.5)	
*Chi square test				

ARI episodes were more among biomass users (37.5%) as compared to LPG users (17.5%). Among those who reported 2 episodes of ARI in past 3 months biomass users are higher in proportion (6.1%) as compared to LPG users (2.4%).

Among children of LPG users 77.5% reported having no ARI episodes in last 3months while only 55.6% children of biomass users had reported to have no ARI. A higher proportion (44.4%) of children belonging to biomass using households reported having at least 1 ARI episode in last 3 months while only 22.5% children of LPG using households reported the same.

Out of 112 children who reported having ARI in last 3 months, 70 were male.

Between the 2 genders it was observed that a higher proportion of male (62.5%) children were affected with ARI. The same is reflected in LPG users (66.7%) and biomass users (62.1%).

Around 90% of children among both LPG users and biomass users were completely immunised.

Households belonging to BPL category are eligible for PMUY (having annual income less than 1lakh). Among the 211 participants who received LPG cylinder from PMUY 60.18% were households eligible for PMUY and 39.81% who received LPG cylinder were not eligible for it.

Table 10: Eligibility criteria of households to receive LPG cylinder under Pradhan Mantri Ujjwala Yojana (PMUY), n=480

	Received cylinder under PMUY		
	Yes	No	p value
Eligible for PMUY*	127 (60.18)	84 (17.5)	<0.001#
Not eligible for PMUY	84 (39.81)	185 (38.54)	

Chi square

* Below 1 lakh BPL

Among those who had received LPG connection through PMUY 39.8% are not eligible for it. And it can also be noted that 17.5% participants who are eligible for PMUY had not received it.

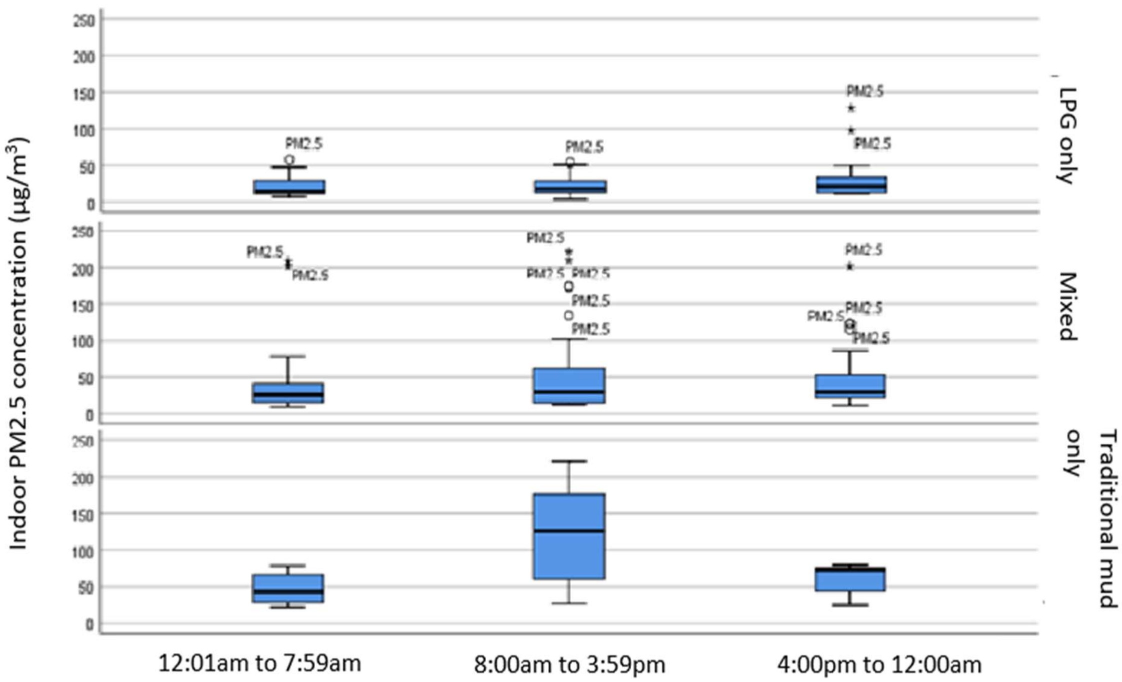


Fig 11: Box plots of 8-hour PM2.5 concentrations by household fuel use pattern among participants. comparing average PM2.5 levels in homes stratified by cooking stoves, n= 113.

The PM2.5 levels have a wider range during 8am to 3:59pm which would represent the main cooking hours of the household. The median PM2.5 concentrations are highest for kitchens with traditional mud stove followed by mixed stove and lastly LPG stove.

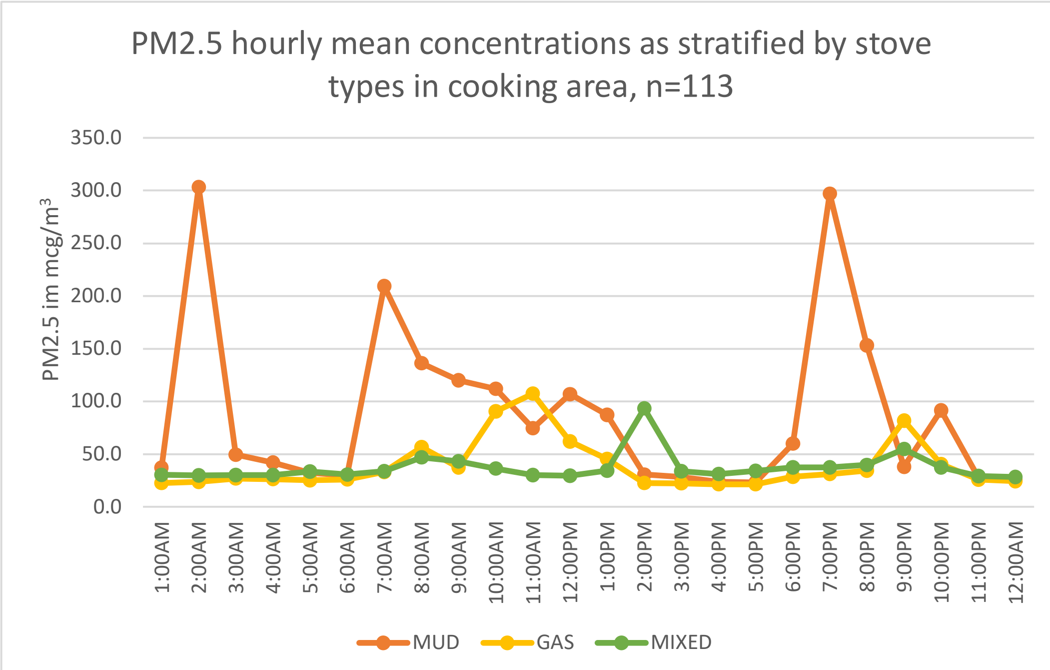


Fig 12: Mean hourly PM2.5 concentrations as stratified by stove types in cooking area, n=113

In households using traditional mud stove it can be noted that PM2.5 levels increase to about 200mcg/m3 during the cooking hours in the morning and around 300mcg/m3 during 7pm to 8pm. Mixed stove using households also show hourly average of around 100mcg/m3 during 1pm to 3pm.

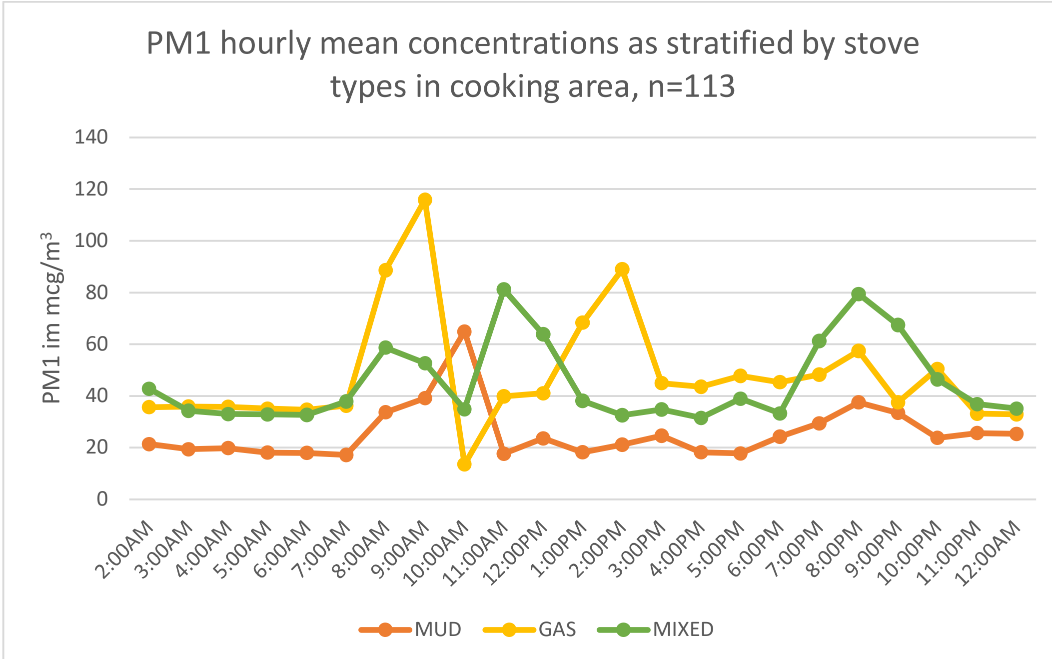


Fig 13: Mean hourly PM1 concentrations as stratified by stove types in cooking area, n=113

PM1 concentrations show peaks for all types of stoves using households. Highest peaks are noted for PM1.

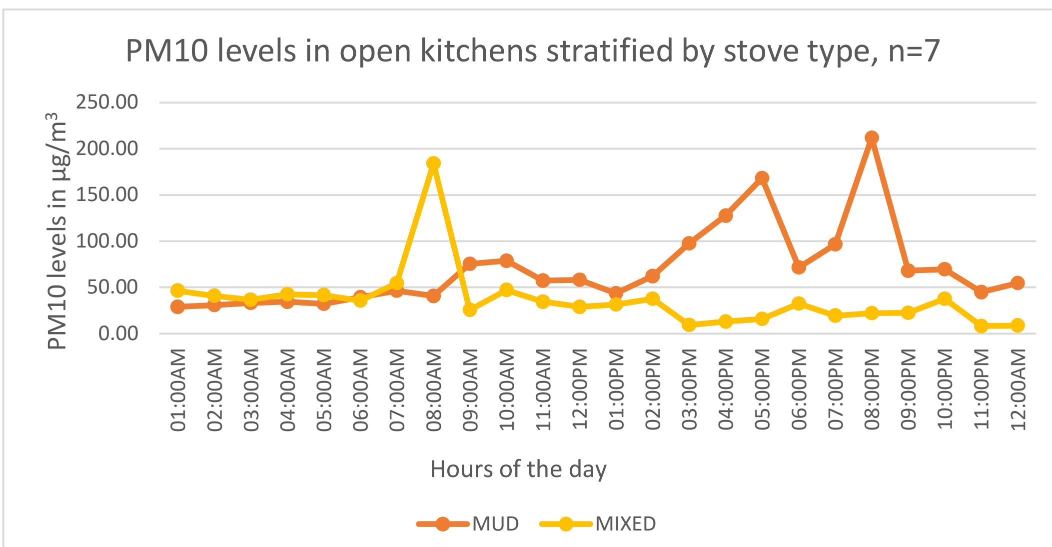


Fig 14: Mean hourly PM10 concentration as stratified by stove types in open cooking area, n=7

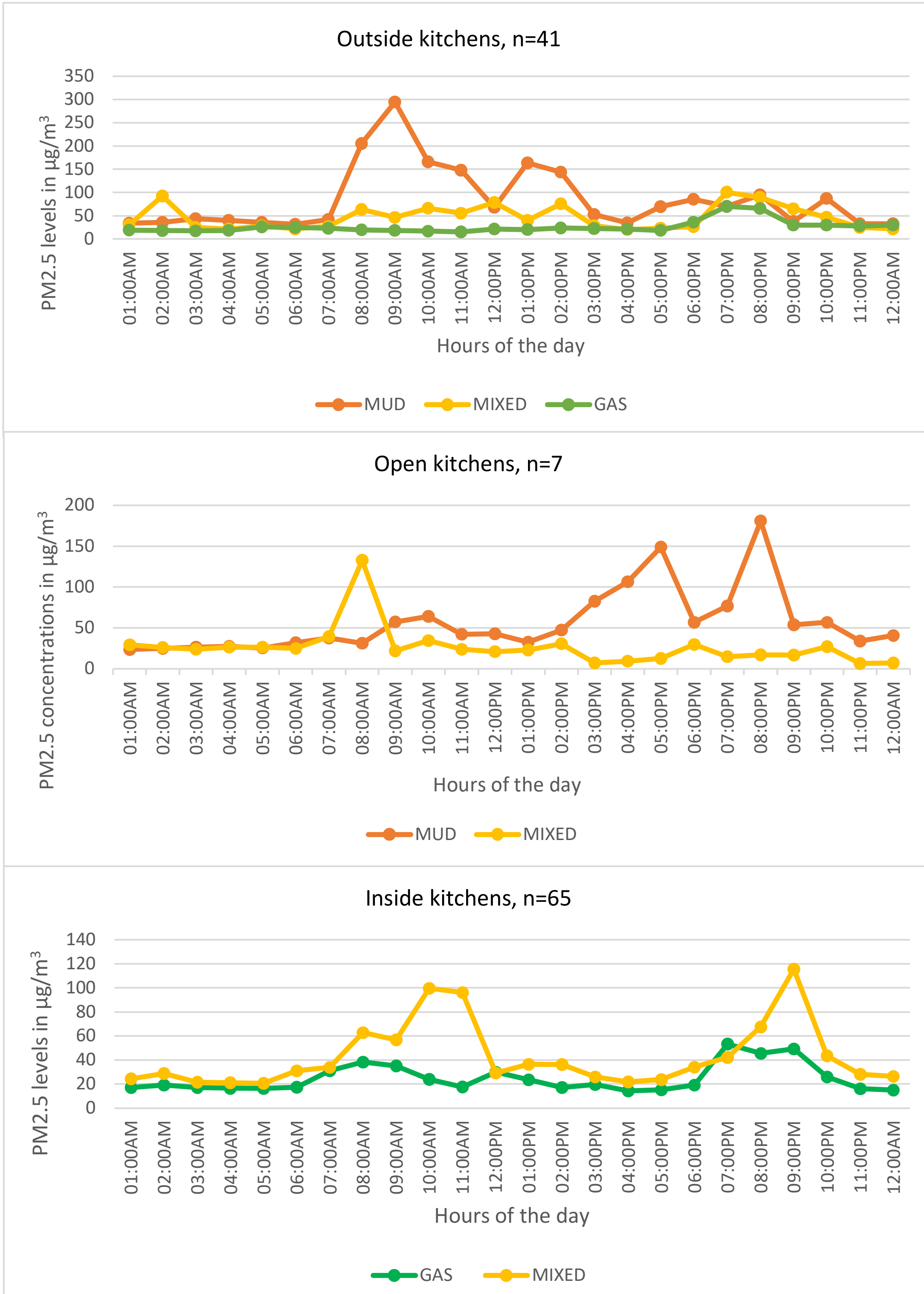


Fig 15: Mean hourly PM2.5 concentrations as stratified by location of kitchen for different stoves, n=113

Graphs show PM2.5 levels across kitchen locations for different stoves. The mixed stove using households located inside have multiple peaks with maximum concentration of 120µg/m^3. While mud traditional stove using households are found to have higher concentrations irrespective of location.

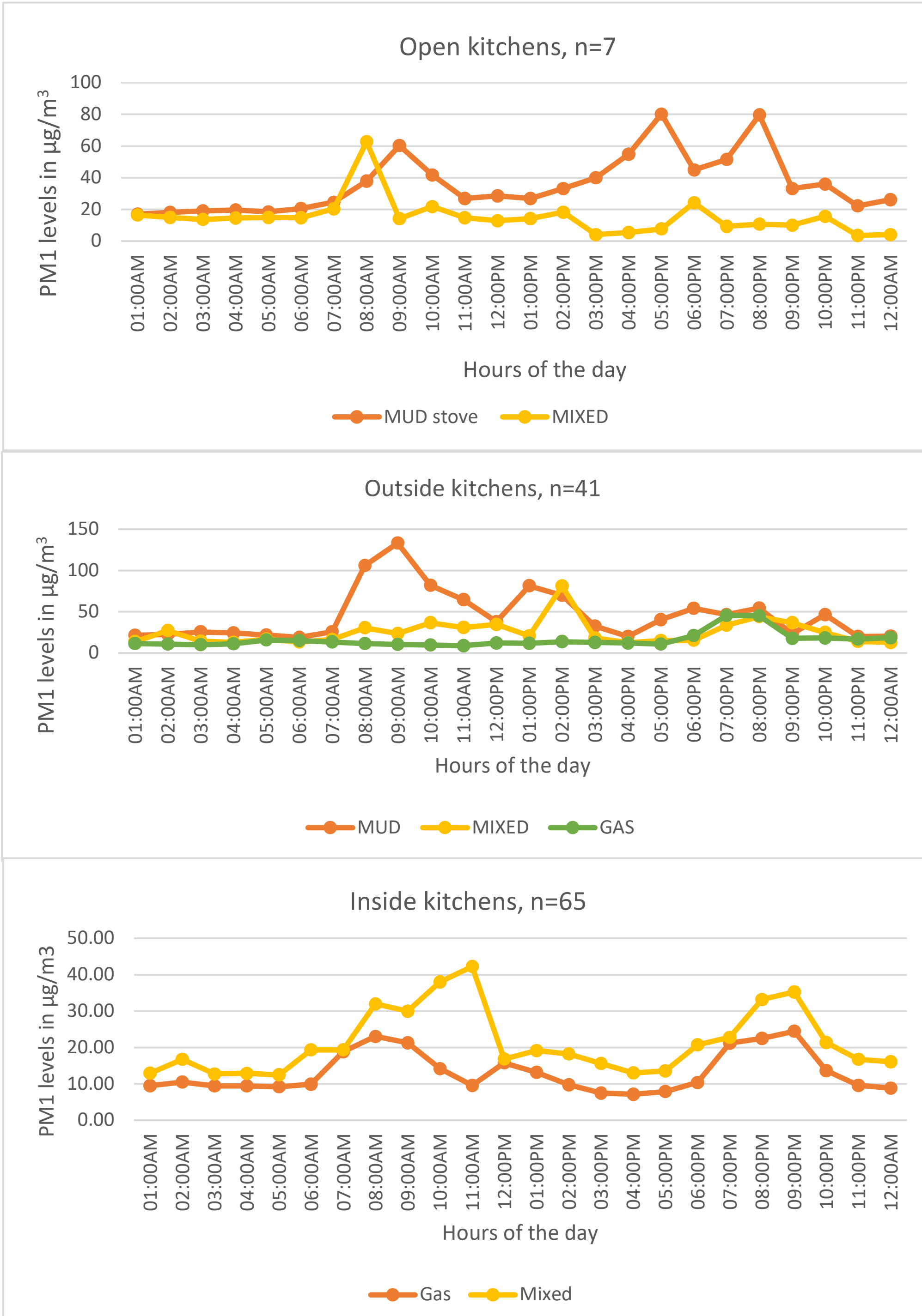


Fig 16: Mean hourly PM1 concentrations as stratified by type of kitchen for different stoves, n=113

Graphs show PM1 levels across kitchen locations for different stoves. The mud stove using households located outside and open are showing high concentrations during certain periods of time.

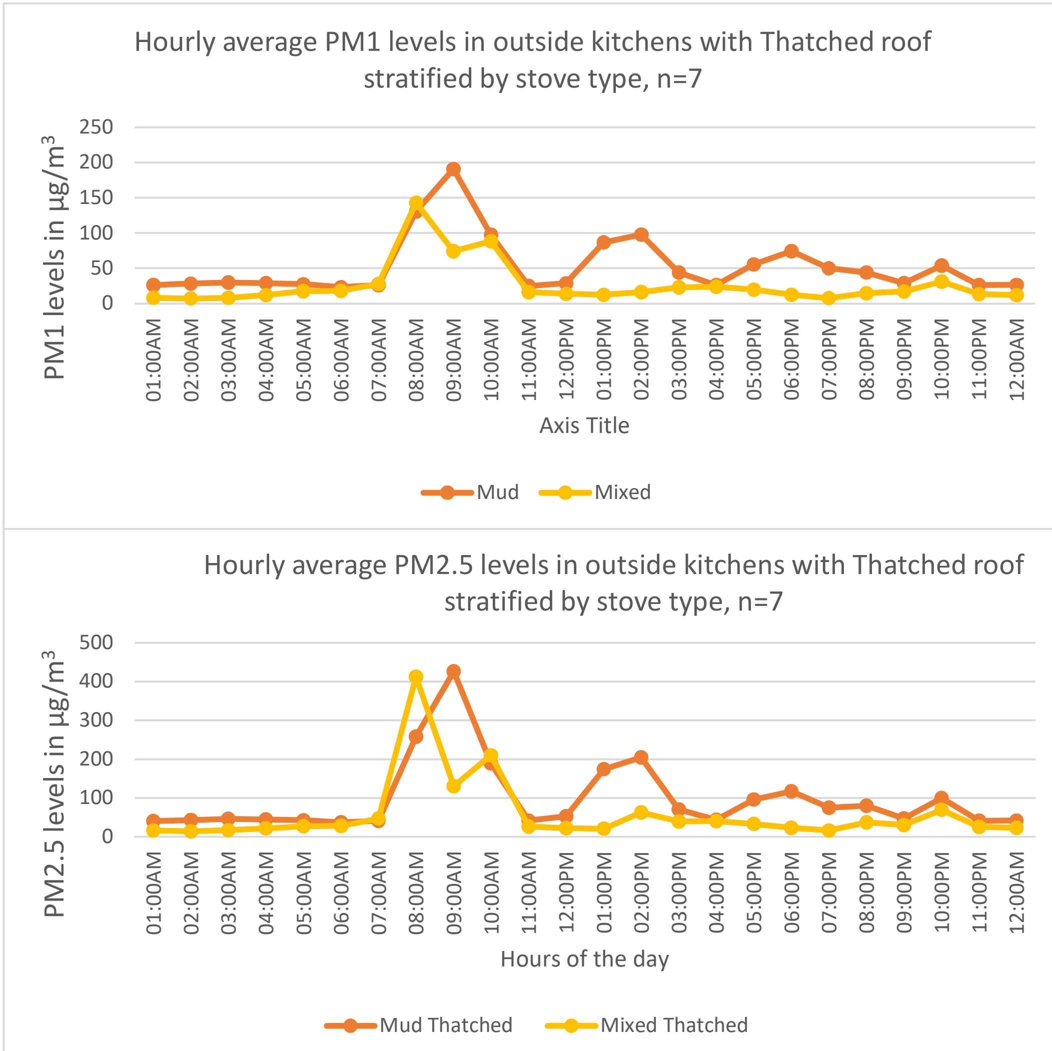


Fig 17: Hourly mean concentrations of PM stratified by different stoves as per roof material for outside cooking area, n=7

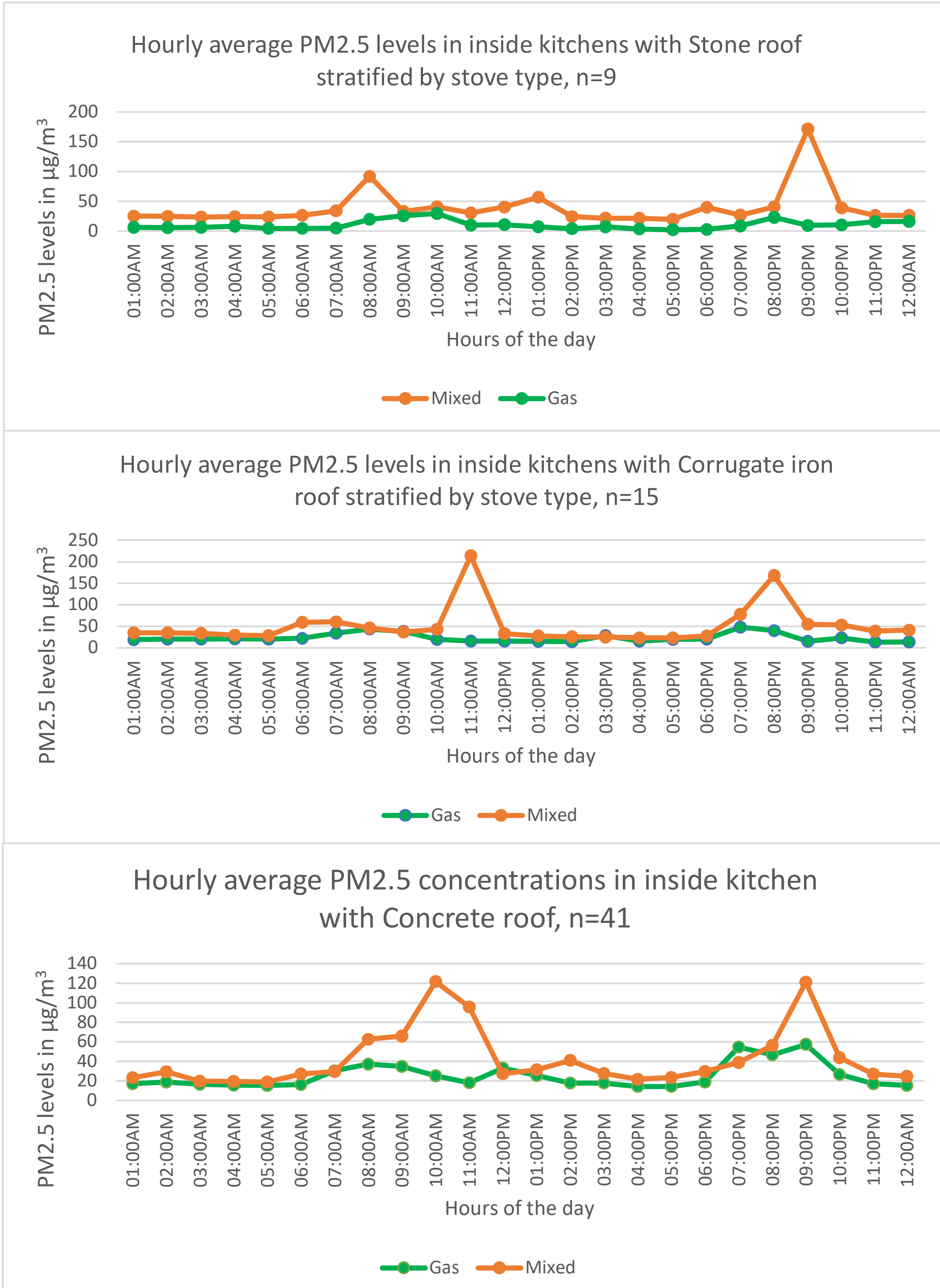


Fig 18: **Hourly mean concentrations of PM2.5 stratified by different stoves as per roof material for inside cooking area, n=65**

The mean PM2.5 concentrations peak for mixed stove kitchen with corrugate iron roof shows highest value followed by stone roof and then concrete roof.

Table 11: Descriptive table of particulate matter for stoves used in the households of women, n=113

Particulate	Stove type	Mean ± SD (in	Median (in	p value	1st quartile	3rd quartile	Min	Max
PM1	Gas, n=27	12.08 ± 7.74	10.22	0.001!	6.96	15.62	1.70	29.15
	Mixed, n=72	19.97 ± 13.84	16.71		9.89	28.27	2.47	85.90
	Mud, n=14	40.603 ± 12.809	37.61		28.36	49.33	20.48	61.15
PM2.5	Gas, n=27	22.01 ± 15.208	18.40	0.001!	10.94	30.05	3.10	59.78
	Mixed, n=72	38.67 ± 29.99	29.30		18.83	48.25	3.88	168.32
	Mud, n=14	75.488 ± 24.54	80.82		52.91	89.90	34.24	114.45
PM10	Gas, n=27	28.09 ± 22.24	21.69	0.001!	14.68	42.05	3.67	106.20
	Mixed, n=72	50.95 ± 44.23	38.44		21.34	70.36	4.16	259.76
	Mud, n=14	90.46 ± 27.25	97.46		68.13	105.305	39.29	133.82
Temperature	Gas, n=27	27.92 ± 8.95	30.49	0.006!	23.49	34.72	5.84	38.57
	Mixed, n=72	30.75 ± 9.27	32.802		30.51	36.50	2.60	49.18
	Mud, n=14	26.51 ± 5.64	23.27		22.50	32.26	20.04	35.10
Humidity	Gas, n=27	49.72 ± 27.37	47.005	0.196	29.93	64.39	9.8	99
	Mixed, n=72	49.59±23.09	46.28		37.24	59.49	0	99
	Mud, n=14	39.67±10.65	36.25		31.55	49.44	31.47	67.11

! Kruskal-Wallis test, at significance level < 0.05

The 24-hour mean PM1 concentrations in kitchens with gas stoves, mixed stoves, and traditional mud stoves were found to be significantly different ($p<0.001$) with the traditional mud stove having mean PM1 concentrations of 40.603 ± 12.81 $\mu g/m^3$, which is greater than the PM1 concentrations other two stove-using kitchens. Similarly, traditional mud stove users had considerably higher 24-hour mean PM2.5 and PM10 concentrations, 75.488 ± 24.54 $\mu g/m^3$ and 90.46 ± 27.25 $\mu g/m^3$ respectively as compared to the other two stoves. There was also a significant difference ($p=0.006$) between the temperatures in the different kitchens.

Table 12: Post hoc analysis of households using different types of stove, n=113

	Mean ± SD					
	Gas	**Mixed**	**Mud**	**p value**	**Comparison groups**	**Post hoc test (P)**
PM1	12.08 ± 7.74	19.97 ± 13.84	40.603 ± 12.809	0.001!	Gas versus mixed	0.012
					Gas versus mud	0.001
					Mixed versus mud	0.002
PM2.5	22.01 ± 15.208	38.67 ± 29.99	75.488 ± 24.54	0.001!	Gas versus mixed	0.015
					Mas versus mud.	0.001
					Mixed versus mud	0.002
PM10	28.09 ± 22.24	50.95 ± 44.23	90.46 ± 27.25	0.001!	Gas versus mixed	0.016
					Gas Versus mud	0.001
					Mixed versus mud	0.010
Temperature	27.92 ± 8.95	30.75 ± 9.27	26.51 ± 5.64	0.006!	Mud versus Gas	0.636
					Mud versus Mixed	0.011
					Gas versus mixed	0.161

! Kruskal-Wallis test, at significance level < 0.05

For PM1, PM2.5, and PM10, post hoc analysis confirmed that there is a significant difference between gas, mixed, and mud stoves. Temperatures were found to differ considerably between mud versus mixed stoves(p=0.011) and gas versus mixed stoves (p = 0.161).

Table 13: Descriptive statistics of 24-hour average particulate matter concentrations across different type of kitchen locations stratified by stove types, n=113

Particulate	Kitchen	Stove type	Mean ± SD (μg/m³)	Median	Minimum	Maximum	p value
PM1	Open	Gas, n=0	-	-	-	-	0.095[@]
		Mixed, n=3	21.64 ± 12.64	17.81	11.55	35.58	
		Mud, n=4	35.14 ± 10.17	32.23	26.78	49.33	
	Inside	Gas, n=25	12.55 ± 7.68	10.22	1.70	29.15	0.006[!]
		Mixed, n=39	19.33 ± 12.14	16.30	3.92	61.14	
		Mud, n=1	61.15	61.15	61.15	61.15	
	Outside	Gas, n=2	10.78 ± 10.45	10.79	3.40	18.18	0.002[!]
		Mixed, n=30	21.15 ± 16.17	20.34	2.47	85.90	
		Mud, n=9	37.11 ± 17.92	37.11	2.85	61.15	
PM2.5	Open	Gas, n=0	-	-	-		0.095[@]
		Mixed, n=3	36.59 ± 19.21	29.30	22.09	58.39	
		Mud, n=4	54.42 ± 3.56	89.91	51.48	89.91	
	Inside	Gas, n=25	23.01 ± 15.26	18.40	3.10	59.78	0.006[!]
		Mixed, n=39	39.35 ± 28.58	30.83	6.23	138.95	
		Mud, n=1	114.45	114.45	114.45	114.45	
	Outside	Gas, n=2	17.86 ± 17.46	17.86	5.51	30.21	0.001[!]
		Mixed, n=30	38.65 ± 32.98	28.62	3.88	168.32	
		Mud, n=9	70.65 ± 33.91	114.45	5.09	114.45	
PM10	Open	Gas, n=0	-	-			0.095[@]
		Mixed, n=3	46.36 ± 18.59	36.96	34.35	67.78	

		Mud, n=4	68.78 ± 1.34	69.29	67.78	105.31	
	Inside	Gas, n=25	29.605 ±22.64	21.69	3.67	106.20	0.008!
		Mixed, n=39	51.78 ± 41.22	39.92	7.05	214.79	
		Mud, n=1	133.82	133.82	133.82	133.82	
	Outside	Gas, n=2	20.305 ± 19.48	20.31	6.58	34.03	0.003!
		Mixed, n=30	50.89 ± 49.78	31.04	4.16	259.76	
		Mud, n=9	86.43 ± 39.46	97.46	5.82	133.82	
@ Mann Whitney u test ! Kruskal Wallis H test							

There were no open kitchens which used gas stoves. Among kitchens located indoors there was only one kitchen which used traditional mud stove exclusively.

The median concentrations of PM1 were highest for mud stove (Open= 32.23v, Inside = 61.15 $\mu g/m^3$, Outside=37.11 $\mu g/m^3$) followed by mixed stoves (Open= 17.81 $\mu g/m^3$, Inside = 16.30 $\mu g/m^3$, Outside=20.34 $\mu g/m^3$) then gas stoves irrespective of kitchen locations.

The median concentrations of PM2.5 was highest for mud stove (Open= 89.91 $\mu g/m^3$, Inside = 114.45 $\mu g/m^3$, Outside=114.45 $\mu g/m^3$) followed by mixed stoves (Open= 29. $\mu g/m^3$, Inside = 30.83 $\mu g/m^3$, Outside=28.62 $\mu g/m^3$) then gas stoves irrespective of kitchen locations.

The median concentrations of PM10 were highest for mud stove (Open= 69.29 $\mu g/m^3$, Inside = 133.82 $\mu g/m^3$, Outside=97.46 $\mu g/m^3$) followed by mixed stoves (Open= 36.96 $\mu g/m^3$, Inside = 39.92 $\mu g/m^3$, Outside=31.04 $\mu g/m^3$) then gas stoves irrespective of kitchen locations.

When comparing PM concentrations between stove locations, it was observed that open kitchens had lower upper limits of PM concentrations than both inside and outside kitchens.

The upper limit of PM1 concentrations vary with location [Gas stove (inside kitchens= 29.15 μg/m^3 vs outside kitchen = 18.18 μg/m^3), Mixed stove (Open = 35.58 μg/m^3, Inside = 61.14 μg/m^3, Outside=85.90 μg/m^3) and Mud stove (Open = 49.93 μg/m^3, Inside = 61.15 μg/m^3, Outside=61.15 μg/m^3).

The upper limit of PM2.5 concentrations vary with location [Gas stove (inside kitchens= 59.78 μg/m^3 vs outside kitchen = 30.21 μg/m^3), Mixed stove (Open = 58.39 μg/m^3, Inside = 138.95 μg/m^3, Outside= 168.32 μg/m^3) and Mud stove (Open = 89.91 μg/m^3, Inside = 114.45 μg/m^3, Outside=114.45 μg/m^3)].

The upper limit of PM10 concentrations vary with location [Gas stove (inside kitchens= 106.20mcg/m3 vs outside kitchen = 34.03mcg/m3), Mixed stove (Open = 67.78 μg/m^3, Inside = 214.79 μg/m^3, Outside=259.96 μg/m^3) and Mud stove (Open = 105.31 μg/m^3, Inside = 133.82 μg/m^3, Outside=133.82 μg/m^3)].

The 24-hour mean PM1, PM2.5, and PM10 concentrations were significantly different ($p<0.001$) across different kitchen sites stratified by gas stoves, mixed stoves, and traditional mud stoves. Inside kitchens with traditional mud stoves had higher mean PM concentrations (PM1 concentration was 61.15 ± 15.79 μg/m^3, PM2.5 concentration was 114.45 μg/m^3, and PM10 concentration was 133.82 μg/m^3) than mixed and gas stoves.

The PM1 concentrations of households with kitchen location inside and using mud stove (61.15μg/m^3) is higher as compared to PM1 concentrations of traditional mud stove using outside kitchen (43.47±8.29 μg/m^3). The mean and median concentrations of PM2.5 was higher in households with kitchen location inside and using mud stove (114.45μg/m^3) as compared to PM2.5 concentrations of traditional mud stove using outside kitchen (85.36± 6.43 μg/m^3 /85.36 μg/m^3).

Table 14: Concentration of PM1, PM2.5 and PM10 in households of women with respiratory symptoms stratified by type of stove, n=113

Particulate matter	Specific respiratory symptoms in last 2 weeks, n=15					Trouble breathing in last 6 months, n=32			
		n (%)	Mean ± SD	Median	p value	n (%)	Mean ± SD (in µg/m3)	Median	p value
PM1	Gas	1 (6.6)	13.42	13.42	0.048!	11(34.4)	9.19 ± 4.96	8.18	0.001!
	Mixed	11(73.4)	24.77 ± 9.87	24.74		17(53.1)	24.60 ± 5.49	24.09	
	Mud	3 (20)	49.37 ± 11.77	49.34		4 (12.5)	49.37 ± 11.77	49.34	
PM2.5	Gas	1 (6.6)	21.19	21.19	0.048!	11(34.4)	16.29 ± 8.49	14.22	0.001!
	Mixed	11(73.4)	50.67 ± 24.16	50.11		17(53.1)	50.73 ± 25.46	49.50	
	Mud	3 (20)	95.06 ± 17.40	89.91		4 (12.5)	95.06 ± 17.40	89.91	
PM10	Gas	1 (6.6)	29.24	29.24		11(34.4)	19.24 ± 9.97	16.27	0.001!
	Mixed	11(73.4)	68.10 ± 32.62	70.94		17(53.1)	67.82 ± 34.37	67.85	
	Mud	3 (20)	112.19 ± 19.13	105.31	0.001!	4 (12.5)	112.19 ± 19.13	105.31	

! Kruskal Wallis H test

Majority (11) of the participants who visited doctor for specific respiratory symptoms in last 2 weeks used mixed stoves in their kitchens. There was significant difference ($p<0.05$) between the PM concentrations in the kitchens of those who had specific respiratory symptoms. Among those who reported trouble breathing in last 6 months ,17 used mixed stoves in their kitchens. Significant difference was noted between the stoves. The difference in PM between the stoves in the kitchens of those who reported trouble breathing in last 6 months was found to be significant ($p<0.05$).

Table 15: Concentration of PM1, PM2.5 and PM10 in households of women who have ever experienced respiratory symptoms stratified by type of stove, n=113

Particulate matter	Ever experienced cough due to smoke from cooking n=48					Ever experienced difficulty breathing due to smoke from cooking n=47			
		n (%)	Mean ± SD (in µg/m3)	Median (in µg/m3)	p value	n (%)	Mean ± SD (in µg/m3)	Median (in µg/m3)	p value
PM1	**Gas**	16(33.3)	8.91 ± 5.06	8.18	0.001!	15 (31.9)	10.20 ± 4.78	8.71	0.001!
	Mixed	27(56.2)	26.20± 17.61	23.43		27 (57.4)	23.25 ± 13.62	21.51	
	Mud	5 (10.5)	32.12± 23.24	26.7		5 (10.6)	32.12 ± 23.24	21.51	
PM2.5	**Gas**	16(33.3)	15.45 ± 8.52	14.22	0.001!	15 (31.9)	18.03 ± 8.47	18.40	0.001!

	Mixed	27(56.2)	54.39± 38.33	45.61		27 (57.4)	50.69 ± 38.90	38.30	
	Mud	5 (10.5)	59.03± 43.61	51.48		5 (10.6)	59.03 ± 43.61	51.48	
PM10	**Gas**	16(33.3)	18.54± 10.32	16.27	0.001!	15 (31.9)	22.20 ± 11.42	21.69	0.001!
	Mixed	27(56.2)	73.20± 57.43	64.53		27 (57.4)	68.38 ± 58.75	52.62	
	Mud	5 (10.5)	70.91± 50.94	70.32		5 (10.6)	70.91 ± 50.94	70.32	
! Kruskal wallis test									

The difference in PM concentrations between those who reported having ever had cough due to smoke from cooking was significant ($p<0.05$) across all types of PM. The same was also observed among those who had ever experienced difficulty breathing due to smoke from cooking.

Table 16: Regression between particulate matter concentrations in households of women with and without specific respiratory problem (Shortness of breath, wheeze or chest tightness), n=113

Variable	Category	OR	95% CI	p value
PM1	Gas	ref		
	Mixed	3.56	0.422 – 30.12	0.243
	Mud	3.08	0.229 – 41.45	0.395
PM2.5	Gas	ref		
	Mixed	3.44	0.40 – 29.19	0.257
	Mud	3.13	0.24- 40.19	0.380
PM10	Gas	ref		
	Mixed	3.58	0.42- 30.21	0.241
	Mud	3.92	0.33- 46.64	0.279

On comparing the participants with respiratory symptoms with 24 -hour mean particulate matter emissions (PM1 and PM2.5) of the different stove types, it was seen that the use of mixed stove (odds ratio [OR] 3.56; 95% confidence interval [CI] 0.422 – 30.12) increased the odds of having respiratory symptoms as opposed to exclusive gas users. The odds were higher among traditional mud stove users (OR 3.92, CI 0.33- 46.64) for PM10 emissions.

Odds of women with respiratory complaints is 3 times higher among women in households using traditional mud stove as compared to exclusive LPG. But none was found significant.

Table 17: Regression between particulate matter concentrations in households of women with and without experience of troubled breathing in last 6 months, n=113

	Category	OR	95% CI	p value
PM1	Gas	ref		
	Mixed	3.33	1.197 - 9.272	0.021
	Mud	5.88	0.992- 34.916	0.051
PM2.5	Gas	ref		
	Mixed	3.59	1.276 - 10.112	0.015
	Mud	6.25	1.099 - 35.582	0.039
PM10	Gas	ref		
	Mixed	3.57	1.266 to 10.088	0.016
	Mud	5.04	0.965 - 26.322	0.055

The chances of women experiencing trouble breathing in the previous 6 months were found to be greater among traditional mud stove users for all PM1, PM2.5, and PM10 emissions (OR 5.88(PM1) CI 0.992- 34.916, 6.25 [PM2.5] CI 1.099 - 35.582, p value 0.039 and 5.04 [PM10] CI 0.965-26.322, p value 0.055 as compared to gas users.

Odds of women who had experienced trouble breathing in last 6 months was 3 times higher for all PM among women in households using traditional mixed stove as compared to exclusive LPG. But for mud it was 5 times higher and was borderline statistically significant.

Table 18: Regression between particulate matter concentrations in households of women with and without ever experiencing cough due to smoke from cooking, n=113

Variables	Category	OR	95% CI	p value
PM1	Gas	ref		
	Mixed	2.85	1.109 – 7.32	0.030
	Mud	4.43	0.910 – 21.61	0.065
PM2.5	Gas	ref		
	Mixed	3.01	1.168 – 7.78	0.023
	Mud	4.97	1.043 – 23.72	0.044
PM10	Gas	ref		
	Mixed	3.01	1.171 – 7.78	0.022
	Mud	4.53	1.012 – 20.31	0.048

Women exposed to PM emissions from traditional mud stoves were more likely to have ever experienced cough due to smoking (OR 4.43 CI 0.910 – 21.61 [PM1], OR 4.97 CI 1.043 – 23.72 [PM2.5], and OR 4.53 CI 1.012 – 20.31 [PM10], with p values 0.065, 0.044, and 0.048, respectively).

Odds of women who had ever experienced cough due to smoke from cooking were 2 to 3 times higher for all PM among women in households using mixed stove as compared to exclusive LPG. But for mud it was 4 times higher and was borderline statistically significant.

Table 19: Binomial logistic regression between particulate matter concentration and ever experienced difficulty breathing among women participants due to smoke from cooking, n=113

Variables	Category	OR	95% CI	p value
PM1	Gas	ref		
	Mixed	2.15	0.852 – 5.44	0.105
	Mud	2.51	0.539 – 11.69	0.241
PM2.5	Gas	ref		
	Mixed	2.45	0.963 – 6.26	0.601
	Mud	3.64	0.787 – 16.90	0.098
PM10	Gas	ref		
	Mixed	2.47	0.973- 6.31	0.057
	Mud	3.46	0.793 – 15.17	0.098

The chances of women having ever experienced difficulty in breathing due to smoke from cooking was more [OR 2.52 CI 0.539 - 11.69 (PM1), OR 3.64 CI 0.787 – 16.90(PM2.5) and OR 3.46, CI 0.793 – 15.17 (PM10)] among traditional mud stove users as compared to gas users.

Odds of women who had ever experienced difficulty breathing due to smoke from cooking was 2 to 3 times higher for all PM among women in households using mixed stove as compared to exclusive LPG. But for mud stove it was 4 times higher and was borderline statistically significant.

Most of the children who were reported to have ARI belonged to households using mixed stove. The PM concentrations of households that had children who reported ARI were lesser.

Table 20: Regression between particulate matter concentration in households of children with and without ARI episodes, n=79

Variables	Univariate regression		
	OR	**95% CI**	**p value**
PM 2.5			
<25	Ref		
>= 25	1.452	0.568- 3.712	0.436

When categorisations of PM2.5 is done based on WHO interim target cut off of 25 $\mu g/m^3$ into normal and abnormal PM2.5 categories, the odds of having ARI is higher (1.452 with 95% CI 0.568- 3.712) with PM2.5 greater than 25 $\mu g/m^3$. PM10 was similarly categorised into normal and abnormal categories and OR of ARI was 0.543 with 95% CI 0.192- 1.536.

Majority of the children with ARI belonged to houses using mixed stove in kitchens.

Chapter 6: DISCUSSION

Aim of the study was to assess the effect of biomass fuels on respiratory morbidities of women and under five children in rural jodhpur. The study also intended to assess the utilization of Pradhan Mantri Ujjwala Yojana (PMUY) among households using biomass fuel.

The current study was carried out in rural Jodhpur, where it was discovered that the usage of biomass fuels was still widespread, despite the advent of liquified petroleum gas via PMUY. People may be at a disadvantage owing to a lack of access to LPG due to higher costs or supply difficulties due to roads, thus they continue to utilise biomass fuels even when LPG stoves are available[59]. There has been no research done in this area to determine the frequency of respiratory morbidity among biomass users.

The mean age of the women participants in the present study was 36 ± 14.72 years and is comparable to the study by **Panigrahi et al (Odisha)**[26] reporting mean age of all participants to be 30.44 ± 6.86 years. The lower mean age in their study might be due to the fact that they only recruited women whereas in the current study age of the participants ranged from 15 to 82 years.

The median age of biomass users [30 (15-82) years] in present study was lower compared to that of LPG users [35 (16 – 82) years]. We hypothesize that the higher median age among LPG users could be attributed to the fact that as women advance in their age their hierarchy in the family increases which gives them more leverage to negotiate for a cleaner and convenient fuel that is also accepted by the family. This is supported by the observation from the study by **Maharana at al (Kolkata)**[59] that younger age was found to be strongly associated with sources of indoor air pollution, with biomass being a key contributor, as seen in our study, where the majority (41%) of biomass users were between ages of 21 and 29.

The present study reported a median age of 30 (15-82) years for women who used biomass fuel, while **Mukherjee et al**[25] reported a median age of 35 (21-45) years. This is because age distribution was skewed in the present study, with the bulk of biomass users falling between the ages of 20 and 29. Only premenopausal women of the age range 23 to 43 years were included in their study. However, all women over the age of 15 were included in the present study, because cooking in rural areas begins as early as 15 years old and continues according to family composition.

The majority of the participants in this study (67.9%) had completed primary school, and the same was true for both groups of fuel users in terms of primary education. This was in line with the findings of **Panigrahi et al (Odisha)**[26]**,** who observed that the majority of participants in both LPG and biomass fuel consumers had completed primary education.

Women who used LPG had a higher proportion of those who finished primary school (80%) than women who used biomass, according to this study (65 %). This was supported by a survey from Kerala by **Gould CF et al**(60)**,** who found that families with a woman who had completed elementary school had a 1.33 times higher likelihood of using LPG (95 % CI: 1.02–1.75) as compared to others.

This was also consistent with **Heltberg et al's**[61] finding (based on survey data of Brazil, Ghana, Guatemala, India, Nepal, Nicaragua, South Africa, and Vietnam) that higher levels of education are linked to a higher chance of using modern fuels and a lower likelihood of using solid fuels.

This demonstrates that greater education and age, through increased understanding of health effects, as well as affluence, which allows for convenience through less time spent foraging for wood and simpler cooking, encourage households to use cleaner fuels**.**

The majority of LPG users (30.5%) had a household income of Rs 20,000 or more, whereas the majority of biomass stove users (37.9%) had a family income of less than Rs 10,000, according to this study. A similar finding was made by **Mukherjee et al**[25] in West Bengal, who found that biomass consumers had lower average family income than LPG users**.**

This fits well with the common observations of the strong income dependency of household fuel use, also known as **the Energy ladder theory which** is a commonly used concept in explaining household fuel use. The energy ladder represents a process in which families shift away from traditional fuels (e.g., biomass), then to intermediate fuels (kerosene, coal), and finally to modern fuels such as LPG and electricity as their income improves further[62].

When stratified according to socioeconomic scale 40% of all participants belonged to upper middle class as per Modified BG Prasad scale for the year 2019.

Only 46 of the 107 upper-class participants in the present study used LPG entirely), while the rest 61 used a combination of fuels or biomass. This was in accordance with **Choudhuri et al**[63], who found [based on analyses of data from the India Human Development Survey (IHDS)] that while clean fuel usage grew with wealth, 65 % of the richest 20% of Indian families use clean fuels, with just 41% relying exclusively on clean fuel. This household-energy-behaviour cannot be explained by the energy ladder hypothesis but can be explained by the concept of "Fuel stacking".

According to the 'Fuel-Stacking' concept, when household wealth rises, they do not totally transition to various fuel types, but tend to consume a combination of fuels. In this, households employ a variety of fuels in their energy consumption, with a mix of fuels from both the lower and upper tiers of the fuel ladder.

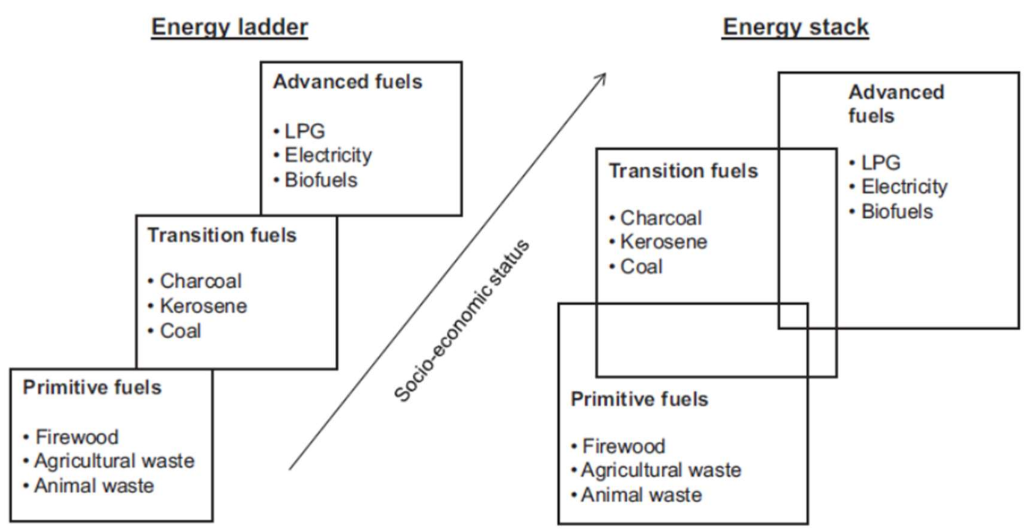


Fig 19: The process of energy transition[64]

According to **Masera et al**[65], households choose to consume a portfolio of energy options at a different point along the energy ladder instead of switching fuels, this process is termed fuel stacking. As family incomes rise, they are more likely to utilise modern fuels for some activities while continuing to use traditional fuels for others, resulting in a 'mixing' of energy sources. The shift to the use of modern fuels takes place in the context of the simultaneous usage of several types of fuels. This could be governed by fuel availability, and the local cultural and social context that determines household preferences regarding cooking fuels and lifestyles.

In this study, it was observed that only 2.1 % of exclusive LPG users were from the lower class (as per modified BG Prasad scale). Around 43% of biomass-using families were in the socioeconomic category of three or more. This was consistent with findings from a cross-sectional survey done by **Sana et al (West Africa)**[29] where they found that cooking fuel choice was highly influenced by socioeconomic class, with individuals with low household wealth having greater odds of using solid biomass fuels [OR-3.02 (2.17–4.20)].

Notable in our study was that more than half of biomass users (56.6%) were aware about Pradhan Mantri Ujjwala Yojana, approximately half of them (47.5%) had applied for it and nearly half (45.5%) had received the cylinder from the programme. The practice of fuel stacking is evident among this group whereby they had used an advanced fuel source in addition to the easily accessible inferior fuel type. Therefore, the programme has allowed penetration of a cleaner fuel into the households but a complete fuel switch to a modern fuel is not commonly observed. The barriers to such adoption should be explored further which could be linked to cultural practices, accessibility of fuel, rising cost of LPG, etc.

One way to assure continuous clean fuel usage is to converge PMUY with other poverty-relieving programmes (MNREGA, Self Help Group Initiative-SHG) to secure livelihood, allowing individuals to buy LPG despite rising LPG prices, and then mandating an LPG stove as a condition of employment.

The adoption of clean household energy in India is hampered by poor households' limited and uncertain disposable income. SHG through providing easy and accessible credit could be used to finance purchase of LPG refills which might drive more widespread use and preference over biomass fuel.

Though PMUY contributed to the increase in LPG connections, it failed to accelerate its consumption demand among the beneficiaries[66]. It is critical to have easy access to financing for refilling LPG cylinders.

The NFHS-5 data set reveals an increased use of improved fuels as compared to previous NFHS (from 43.8% to 58.6%). This could be due to increased availability of gas connection through PMUY enabling better penetration of cleaner fuels into households[67].

So, while the programme has enabled the adoption of a cleaner fuel, a complete fuel transition to a contemporary fuel would necessitate convergence across other initiatives to assure livelihood, allowing people to purchase LPG despite rising LPG prices.

In this study participants reported a median duration of 2 hours of cooking by LPG users and 1 hour by biomass users. Most (66.3%) LPG users spent 1 to 2 hours cooking while majority (70.1%) of biomass users reported cooking for 1 hour or less. The increased duration of cooking by LPG users could be related to increased family size or convenience of cooking as it is also observed in our study that the frequency of cooking is also higher among LPG users as compared to biomass users.

In the present study majority (85%) of children were living in houses using biomass fuel and only 15% were in households using LPG. This is similar to findings from the study by **Patel et al (Uttar Pradesh)**[68]**.** In their study 86% of children were belonging to houses using biomass fuels and 13% in households using LPG only. The sample population of our study had 54.8% male and 45.2% female children. This is consistent with the census data of India (2011) in which the proportion of male children was 53.08% and female children was 46.94% **(Census 2011)**[69]**.** Similar finding was seen in the study by **Mishra et al (Zimbabwe)**(70) where their sample population consisted of almost equal proportion of male and female children (48.66% male and 51.34% female)**.** Children living in biomass-using households were nearly equally distributed across gender groups (48.3% females and 51.7 % males). The majority of children in this study were between the age of 24 and 35 months old.

In our study, according to the Modified BG Prasad scale for the year 2019, 39.7% of children were in upper middle-class households. Among the children of biomass using households 41.8% were in upper middle class. The proportion of partially immunized children were very small in both categories of households.

Majority of the LPG stove using kitchens had concrete roof, while none of these houses had thatched roofs or no roofs. But the condition was different for biomass using kitchens where 6.2% households had no kitchen at all and 12.5 % have thatched roofs. A large proportion of the households had 4 to 5 members in the family. In an article by **Pollard**

et al[44], it was mentioned that the stove choice may not be associated with the number of family members. Similar observation was made in our study also that family size did not affect the fuel preference.

In our study the mean years of cooking of the participants on traditional mud stove was 21.46 ± 15.02 years with a range between 0 to 60 years. This is similar to the findings from the study by **Johnson et al (Tamil Nadu)**[20] in which the exposure to cooking with biomass stove was 29.3 ± 11.2 years among women.

The fuel usage pattern among households in our study (biomass fuel in 80.2 % and 19.8% used LPG only) was consistent with the findings of study by **Johnson et al**[20]. In their study 83.7% participants used biomass fuel and only 16.3% used cleaner fuels (LPG and kerosene).

Wood, which accounted for 72 % of the fuel used in traditional mud stoves, was the favoured fuel among biomass fuel users. This was similar to the findings by **Pollard et al**[44] where they had observed that 69.2% of participants used wood. Only 7.86 % relied only on cow dung as a source of energy. The usage of cow dung as a fuel was even less popular among secondary traditional mud stove users, with only 3.84 % opting for it.

In the current study there was no seasonal variation seen in cooking fuel usage. Participants continued the same pattern of fuel and stoves usage throughout the year.

During the two weeks period preceding to contact, 103 of the recruited women had seen a doctor. Among them 20.38% availed treatment for wheeze, 9.7% for shortness of breath and 5.82% for chest tightness. This was in contrast with study by **Panigrahi et al**[26] **and Jindal et al**[72] where it was found that wheeze was seen in only 10.18% of all participants and 2.6% respectively. In their study they had captured respiratory symptoms of participants in the 12 months preceding survey. They had reported shortness of breath in 16.88%, which is higher than that in our study. Similarly, their study reported that 18.39% people experienced chest tightness. In a study by **Suksohale et al (Nagpur)**[21] shortness of breath was reported by only 1.7% of all participants which is also in contrast with the present study. There was a hesitancy among the participants in revealing respiratory symptoms due to ongoing COVID 19 pandemic. As per the government guidelines for COVID19 testing (dated 18/05/2020)[73] patients experiencing following symptoms: Fever and cough in last 10 days were required to notify and get themselves tested for COVID

19. (WHO case definition for ILI: Individual presenting with acute respiratory infection with fever ≥ 38◦C and cough with onset within the last 10 days)[74]**.** On testing positive these patients were shifted to isolation facilities. A considerable fear was palpable among studied population that on reporting symptoms they will be tested for COVID 19.

PM1, PM 2.5, and PM 10 levels were measured in kitchens that solely used LPG, biomass kitchens that used traditional mud stoves, and mixed fuel kitchens.The distribution of mean concentrations of PM1, PM2.5 and PM 10 from different fuel types are shown in Fig 11 to 18.

In the present study the mean PM2.5 values in traditional mud stove using homes was found to be 75.488 ± 24.54 mcg/m3 which is similar to the values reported by **Deepthi et al (Telangana)**[39] which was 117.54 µg/m3. In their study the PM concentrations in households with biomass and with combination of biomass and LPG were 3.8 and 1.7 times that of values in households using LPG only. The study by **Panigrahi et**[26] al also reports that PM2.5 levels were higher in biomass using households whether it was biomass fuel alone or as mixed fuel. The present study also reported PM2.5 concentrations to be ranging from 34 to 114mcg/m3 in traditional mud stove using households. In households using mixed fuel PM 2.5 values have been found to be in the range of 3.88 to 168.32 mcg/m3.

PM2.5 concentrations were found peaking to 200 mcg/m3 and above for traditional mud stove users (fig 6) and high PM1 values were noted for all of mud stove , mixed stove and LPG only stove using kitchens.

The mean PM1 values range from 20.48mcg/m3 to 61.15mcg/m3 in Traditional mud stove using households. PM1 level means ranged between 1.70mcg/m3 to 29.15mcg/m3 in households having LPG stove. As for households using mixed stove PM1 value means ranged between 2.47mcg/m3 to 85.90mcg/m3. The mean PM2.5 values range from 34.24 mcg/m3 to 114.45mcg/m3 in traditional mud stove using households. PM2.5 level means ranged between 3.10mcg/m3 to 59.78mcg/m3 in households having LPG stove. As for households using mixed stove PM2.5 values ranged between 3.88mcg/m3 to 168.32mcg/m3 (Table 11). The study by **Arif et al(Sitapur, Patna , Murshidabad)**[30] also shows varying range of PM2.5 among biomass using households where they have reported PM2.5 to be in the range of 45.31 to 634.65mcg/m3. The PM2.5 values in households using LPG are notably less in the range of 10.67 to 60.06 mcg/m3 which was similar to our study. The mean PM10 values range from 4.15 mcg/m3 to 99mcg/m3 in traditional mud stove using households. PM10 level means ranged between 3.67mcg/m3 to 106.20 mcg/m3 in households having LPG stove. As for households using mixed stove PM10 values ranged between 4.16 mcg/m3 to 259.76 mcg/m3. This was consistent with PM10 values reported in study by **Arif et al**[30] where they have found PM10 values ranging from as low as 58.90mcg/m3 to 825.04mcg/m3. Higher values of PM2.5 and PM10 , 600.65mcg/m3 and 965.54mcg/m3 respectively are reported by **Deepthi et al**[39].

The values found in this study was comparable with previous studies in Bangladesh by World bank **(Dasgupta et al)**[75] and that of **Deepthi et al**[39] in Telangana. The 24 hour mean PM2.5 of traditional mud stove using kitchens was 75.48 ± 24.54 mcg/m3 and PM10 concentrations was 90.46 ± 27.25 mcg/m3 which are higher than the WHO indoor air quality standards of 24 hr mean PM2.5 of 15mcg/m3 and PM10 24 hr mean of 45mcg/m3. The study by **Deepti et al**[39] reports mean concentrations of 179 mcg/m3 for PM10 , 102 mcg/m3 PM2.5 and 67 mcg/m3 PM1 for biomass using households which is consitent with the findings of the present study. The study by **Dasgupta et al**[75] which monitored indoor air pollution in 236 households reports mean PM10 concentrations of 260 mcg/m3. This study also reports a diurnal peaking or two peaks of increased PM 10 concentrations during cooking times which can also be noted in the present study where there is one peak during morning cooking time and a smaller peak late into the day or evening hours. This value maybe indicative of the persistence of particulate matter in the atmosphere even after cooking has stopped in the kitchens. Because of which the exposure of particulate matter to women and children are continued long after cooking is over with biomass fuels.

The median concentrations of PM10 were highest for mud stove (Open= 69.29mcg/m3, Inside = 133.82 $\mu g/m^3$, Outside=97.46 $\mu g/m^3$) followed by mixed stoves (Open= 36.96 $\mu g/m^3$, Inside = 39.92 $\mu g/m^3$, Outside=31.04$\mu g/m^3$) then gas stoves (Inside = 21.69 $\mu g/m^3$, Outside=20.31 $\mu g/m^3$) irrespective of kitchen locations.

The upper limit of PM1 concentrations vary with location [Gas stove (inside kitchens= 29.15 $\mu g/m^3$ vs outside kitchen = 18.18mcg/m3), Mixed stove (Open = 35.58 $\mu g/m^3$, Inside = 61.14 $\mu g/m^3$, Outside=85.90 $\mu g/m^3$) and Mud stove (Open = 49.93 $\mu g/m^3$, Inside = 61.15 $\mu g/m^3$, Outside=61.15 $\mu g/m^3$).

The highest limit of PM2.5 concentrations for gas stoves (inside 59.78, outside 30.21), mixed stoves (open 58.39, inside 138.95, outside 168.32), and mud stoves (inside 138.95, outside 168.32) varies depending on location (open89.91 , inside 114.45 outside 114.45).

When comparing PM concentrations amongst stove locations in the current study, open kitchens had a lower maximum limit of PM concentrations than kitchens placed indoors and outside. This demonstrates that the location of stoves affects PM concentrations, as explained by **Ravindra Khaiwal et al**[76] in their review, where he presents solutions/measures for reducing indoor air pollution, such as separating the cooking area from living areas, providing proper ventilation in kitchens, and installing chimneys to vent smoke.

In the present study the hourly mean PM 2.5 concentrations were observed to be as high as 180 mcg/m3 for mud stove with two peaks between 3pm to 9pm . The same pattern was observed for PM 10 concentrations. This was similar to findings by **Arif et al**[30] **(**with mean ranging from 12.05 to 298.78 μg/m^3**)** with highest PM10 concentrations during evening cooking hours.

The hourly average PM2.5 in outside/outdoor kitchens in our study showed a peak of 300mcg/m3 which maintained high concentrations from 8am to 2 pm . This was also similar to that reported by **Arif et al**[30] where they had highest concentration of 215.12mcg/m3.

The inside kitchen PM2.5 shows highest concentration in evening hours which is 120mcg /m3 and is similar to findings in study by **Arif et al**[30]) where he has reported highest PM2.5 in evening at 183.4mcg/m3.

In our study it was observed that PM2.5 concentrations were higher in traditional mud stove using kitchens with thatched and stone roofs viz. 84.45 ± 20.32 mcg/m3 and 102.18 ± 17.36 mcg/m3. This was consistent with the findings of **Pollard et al**[44] where they had observed that PM concentrations were higher in households with thatched roof. This could be due to the construction of thatched kitchens where there was no ventilation and also due to previously deposited PM.

Households with indoor kitchens showed peak PM2.5 concentrations of 100 and 120 mcg/m3 for mixed fuel users. This corresponded to the main cooking hours of the households from 8am to 11am and 7pm to 10pm.

The presence of chimney did not result in reduced PM concentrations in the kitchens. This could be due to the fact that majority of the chimneys reported to be present in the kitchens were actually eave gaps and did not provide much ventilation.

In the study by **Dasgupta et al**[58] the households monitored (n=422) for particulate matter used different types of fuel such as dung , firewood, sawdust , straw , jute, twigs and kerosene of which majority used wood(159/430) and dung (95/430). But in the present study it was observed that households used wood (80.51%), cow dung (6.23%) and a combination of wood & cow dung (13.24%) as these were the most commonly available fuels that were easily sourced as by products from farming in the area.

The peak in hourly average concentrations of PM10 in open kitchens were noted to around 200 mcg/m3 for women working in kitchens with traditional mud stove. The daily 24 hour average PM10 concentration was 90.46 ± 27.25mcg/m3 (median 97.46 mcg/m3) which was almost double the protective limit. In the World bank study by **Dasgupta et al (Bangladesh)**[75] the daily average PM10 exposure for women were reported to range between 156 to 264mcg/m3 which was at least 3times WHO recommended PM10 concentrations.

The 24 hr average PM10 exposures among children in households using gas, mixed fuel and mud stove was 24.14 mcg/m3 , 48.93 mcg/m3 and 82.51 mcg/m3 respectively in the current study. Even among children in traditional mud stove using households PM10 exposure was almost twice the recommended limit (82.51 mcg/m3). High levels of PM10 exposure was observed for children PM10 concentrations in our study for traditional mud stove using women ranged between 50 to 200 mcg/m3 and for mixed users the PM10 concentration was uniform except for a peak concentration of around 180mcg/m3 between 7am to 9am. It has been observed in our study that there is more or less a uniform concentration of PM with a spike during cooking hours. These peaks could possibly lead to disproportionate health damage which requires further research to understand the propensity of damage the intense pollution levels could cause.

In our study, we discovered that PM concentrations are more or less constant throughout the day, with a peak around cooking hours. These peaks may create disproportionate health harm, necessitating more research to determine the extent of the harm that high pollution levels may cause.

Chapter 7: STRENGTHS AND LIMITATIONS

Strengths of the current study

To our knowledge this was the first rural community based study conducted in Rajasthan to capture particulate matter concentration in houses and the proportion of households using exclusive LPG; exclusive traditional mud stove and mixed fuel.

This was also the first study to assess the extent to which the Pradhan Mantri Ujjwala Yojana programme was implemented and utilised in rural Rajasthan.

Monitoring of houses for indoor air pollution was done for a period of 24 hours to capture the concentration of PM 1, 2.5 and 10 in households using exclusive gas, exclusive biomass fuel and mixed fuel. This enabled recording of baseline indoor air PM concentration and identifying of hours during which peak of PM concentrations is experienced.

Limitations

The current study is a cross sectional study thus causal relationships cannot be established. During the period this study was conducted (Jan 2020 to July 2021) the whole country was experiencing COVID 19 pandemic and nationwide lockdown was imposed. Thus, many of the initial methodology steps were modified to enable data collection. The initially planned community-based study to be conducted through house-to-house survey could not be conducted.

Rather, the study setting was shifted to rural primary health centre and women visiting the health facility were enrolled as study participants. Thus, the convenience sampling adopted due to COVID 19 pandemic limits the generalisability of study findings to the rural population. Thus, majority of data collected was as per reported by women participants and could not be supplemented by household level observations. The self-reported data by women limited data usability in capturing and interpreting many crucial aspects regarding details of households; kitchen location ; presence and use of chimneys and seasonal variations in fuel preference and use. Further the health outcomes of women could not be assessed through spirometry to ensure following of COVID 19 appropriate behaviour. This was as per recommendations by ERS and Lung India guidelines where spirometry restricted use was recommended only among patients where it was absolutely necessary. Thus, the impact of biomass fuel on lung function could not be assessed

Chapter 8: CONCLUSION

Fuel choice significantly affects indoor air particulate matter concentration and health of women causing increased frequency of respiratory symptoms among women and children as observed in current study.

In this study we have investigated the determinants of indoor air pollution and exposure to indoor air pollution in rural Jodhpur. Although participants' concern of COVID 19 isolation may have resulted in a lower proportion of self-reported symptoms, LPG users reported a larger proportion of having ever had respiratory morbidities. This implied that symptomatic biomass fuel consumers are probably switching to cleaner fuel.

LPG adoption and households with continued use of exclusive LPG experiences lower 24 hourly and hourly mean particulate matter concentration. Integrated policies to enable sustained energy access and adoption will have clear health benefits, influencing the burden of NCD’s in rural India.

Emphasis on LPG use can play an essential role in achieving reduction in household air pollution by 50%, as envisaged under the NCD prevention targets in India.

PMUY provided LPG connections and cylinders to around half of the participants, yet the bulk of them continue to use biomass fuel. This necessitates a reassessment of the programme or the establishment of new policies to enable marginalised individuals to utilise cleaner fuels, allowing the SDG and WHO objectives to be attained in the long run.

Chapter 9: RECOMMENDATIONS

Recommendations for Service & Policy

LPG adoption has expanded with implementation of the PMUY initiative. But the reason to integrate cleaner fuel into daily lives of women and its health impacts need more emphasis and must be clearly conveyed to the consumers through the campaigns. Involving community workers viz ASHA workers , AWW, knowledge regarding health benefits of clean fuel and societal benefits of adoption of clean fuel could prove effective in enhancing knowledge among end users.

PMUY enables initial adoption of LPG but the financial barrier to continued use and refills have to be overcome. Thus, focus on ensuring livelihood through jobs and schemes is an essential area to sustain the benefits of PMUY.

Evidence exists that indoor particulate matter concentration can be lowered by improving ventilation through changes in house architecture including installation of chimneys in kitchen. Propagating these simple and cost- effective interventions through involvement of gram panchayats could play an instrumental role in enhancing adoption among rural households.

Recommendations for future Research

During the study period it was observed in houses monitored for PM that there were peaks with high concentrations coinciding with cooking activities. Health damages during these brief exposures to high levels of particulate matter concentration is an under-researched area and warrant exploratory studies in future.

The barriers for adoption or continued use of LPG have to be addressed through qualitative studies which would reveal the drivers of sustained use of LPG and cessation of biomass fuel use. This information can be employed to make necessary policy action to be implemented for improving use of clean fuel.

Many of the women who reported respiratory issues were utilising LPG exclusively; but they were doing so because they were experiencing respiratory difficulties while using biomass fuel. Future research must take into account the determinants that prompt exclusive use of LPG even in households with lower socio-economic status and the factors that played an instrumental role in end consumer decision of switching to exclusive LPG over mixed fuel use.

BIBLIOGRAPHY

1. Household air pollution and health [Internet]. [cited 2019 Nov 12]. Available from: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

2. Air pollution [Internet]. [cited 2019 Nov 12]. Available from: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

3. State-wise PMUY Connections Released [Internet]. [cited 2019 Nov 14]. Available from: https://pmuy.gov.in/released-connections.html

4. Smith KR, Aggarwal AL. Air pollution and rural biomass fuel in developing countries: a pilot study in India and implications for research and policy, Atmosphere and Environment 17(11. 1983.

5. Guilbert JJ. The world health report 2002 - reducing risks, promoting healthy life. Educ Health Abingdon Engl. 2003 Jul;16(2):230.

6. Fullerton DG, Bruce N, Gordon SB. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. Trans R Soc Trop Med Hyg. 2008 Sep 1;102(9):843–51.

7. Agrawal S, Yamamoto S. Effect of Indoor air pollution from biomass and solid fuel combustion on symptoms of preeclampsia/eclampsia in Indian women. Indoor Air. 2015 Jun;25(3):341.

8. Albalak R, Frisancho A, Keeler G. Domestic biomass fuel combustion and chronic bronchitis in two rural Bolivian villages. Thorax. 1999 Nov;54(11):1004.

9. New WHO Global Air Quality Guidelines aim to save millions of lives from air pollution [Internet]. [cited 2022 Feb 10]. Available from: https://www.who.int/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution

10. Murray CJL, Aravkin AY, Zheng P, Abbafati C, Abbas KM, Abbasi-Kangevari M, et al. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet. 2020 Oct 17;396(10258):1223–49.

11. Household air pollution and health [Internet]. [cited 2022 Feb 9]. Available from: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

12. Brauer M. HEALTH IMPACTS OF BIOMASS AIR POLLUTION. 1999;69.

13. Ritchie H, Roser M. Indoor Air Pollution. Our World Data [Internet]. 2013 Nov 16 [cited 2022 Feb 9]; Available from: https://ourworldindata.org/indoor-air-pollution

14. Martin. Why the SDGs Matter [Internet]. United Nations Sustainable Development. [cited 2022 Feb 9]. Available from: https://www.un.org/sustainabledevelopment/why-the-sdgs-matter/

15. Census of India Website : Office of the Registrar General & Census Commissioner, India [Internet]. [cited 2022 Feb 4]. Available from: https://censusindia.gov.in/2011-common/censusdata2011.html

16. Tracking SDG 7 | Progress Towards Sustainable Energy [Internet]. [cited 2022 Feb 10]. Available from: https://trackingsdg7.esmap.org/

17. National Clean Air Programme (NCAP) for Indian cities [Internet]. CEEW. 2020 [cited 2022 Feb 12]. Available from: https://www.ceew.in/publications/national-clean-air-programme-ncap-indian-cities

18. PMUY : About [Internet]. [cited 2022 Feb 10]. Available from: https://www.pmuy.gov.in/about

19. National Family Health Survey [Internet]. [cited 2022 Feb 10]. Available from: http://rchiips.org/nfhs/about.shtml

20. Johnson P, Balakrishnan K, Ramaswamy P, Ghosh S, Sadhasivam M, Abirami O, et al. Prevalence of chronic obstructive pulmonary disease in rural women of Tamilnadu: implications for refining disease burden assessments attributable to household biomass combustion. Glob Health Action [Internet]. 2011 Nov 3 [cited 2019 Nov 12];4. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3208970/

21. Sukhsohale ND, Narlawar UW, Phatak MS. Indoor Air Pollution from Biomass Combustion and its Adverse Health Effects in Central India: An Exposure-Response Study. Indian J Community Med Off Publ Indian Assoc Prev Soc Med. 2013;38(3):162–7.

22. Dutta A, Ray MR. Hypertension and respiratory health in biomass smoke-exposed premenopausal Indian women. Air Qual Atmosphere Health. 2014 Jun 1;7(2):229–38.

23. T JBR. Altered Lung Function Test in Asymptomatic Women Using Biomass Fuel for Cooking. J Clin Diagn Res JCDR. 2014 Oct;8(10):BC01.

24. Agrawal S. Effect of Indoor Air Pollution from Biomass and Solid Fuel Combustion on Prevalence of Self-Reported Asthma among Adult Men and Women in India: Findings from a Nationwide Large-Scale Cross-Sectional Survey. J Asthma Off J Assoc Care Asthma. 2012 May;49(4):355.

25. Mukherjee S, Roychoudhury S, Siddique S, Banerjee M, Bhattacharya P, Lahiri T, et al. Respiratory symptoms, lung function decrement and chronic obstructive pulmonary disease in pre-menopausal Indian women exposed to biomass smoke. Inhal Toxicol. 2014 Dec 1;26(14):866–72.

26. Panigrahi A, Padhi BK. Chronic bronchitis and airflow obstruction is associated with household cooking fuel use among never-smoking women: a community-based cross-sectional study in Odisha, India. BMC Public Health. 2018 Jul 27;18(1):924.

27. Rabha R, Ghosh S, Padhy PK. Effects of biomass burning on pulmonary functions in tribal women in northeastern India. Women Health. 2019 Mar;59(3):229–39.

28. Kurmi OP, Semple S, Devereux GS, Gaihre S, Lam KBH, Sadhra S, et al. The effect of exposure to biomass smoke on respiratory symptoms in adult rural and urban Nepalese populations. Environ Health [Internet]. 2014 [cited 2022 Feb 12];13. Available from: https://www.ncbi.nlm.nih.gov/labs/pmc/articles/PMC4232609/

29. Sana A, Kafando B, Dramaix M, Meda N, Bouland C. Household energy choice for domestic cooking: distribution and factors influencing cooking fuel preference in Ouagadougou. Environ Sci Pollut Res Int. 2020 May;27(15):18902–10.

30. Arif M, Parveen S. Carcinogenic effects of indoor black carbon and particulate matters (PM2.5 and PM10) in rural households of India. Environ Sci Pollut Res. 2021 Jan 1;28(2):2082–96.

31. Huang Y, Wang J, Fu N, Zhang S, Du W, Chen Y, et al. Inhalation exposure to size-segregated fine particles and particulate PAHs for the population burning biomass fuels in the Eastern Tibetan Plateau area. Ecotoxicol Environ Saf. 2021 Mar 15;211:111959.

32. Stapleton EM, Puliyakote AK, Metwali N, Jeronimo M, Thornell IM, Manges RB, et al. Lung function of primary cooks using LPG or biomass and the effect of particulate matter on airway epithelial barrier integrity. Environ Res. 2020 Oct;189:109888.

33. Fandiño-Del-Rio M, Kephart JL, Williams KN, Moulton LH, Steenland K, Checkley W, et al. Household air pollution exposure and associations with household characteristics among biomass cookstove users in Puno, Peru. Environ Res. 2020 Dec 1;191:110028.

34. Kephart JL, Fandiño-Del-Rio M, Koehler K, Bernabe-Ortiz A, Miranda JJ, Gilman RH, et al. Indoor air pollution concentrations and cardiometabolic health across four diverse settings in Peru: a cross-sectional study. Environ Health. 2020 Jun 3;19(1):59.

35. Fatmi Z, Ntani G, Coggon D. Levels and Determinants of Fine Particulate Matter and Carbon Monoxide in Kitchens Using Biomass and Non-Biomass Fuel for Cooking. Int J Environ Res Public Health [Internet]. 2020 Feb [cited 2022 Feb 13];17(4). Available from: https://www.ncbi.nlm.nih.gov/labs/pmc/articles/PMC7068500/

36. Benka-Coker ML, Peel JL, Volckens J, Good N, Bilsback KR, L'Orange C, et al. Kitchen concentrations of fine particulate matter and particle number concentration in households using biomass cookstoves in rural Honduras. Environ Pollut Barking Essex 1987. 2020 Mar;258:113697.

37. Sharma D, Jain DS. Impact of intervention of biomass cookstove technologies and kitchen characteristics on indoor air quality and human exposure in rural settings of India. Environ Int. 2018 Dec 11;123:240–55.

38. Qi M, Du W, Zhu X, Wang W, Lu C, Chen Y, et al. Fluctuation in time-resolved PM2.5 from rural households with solid fuel-associated internal emission sources. Environ Pollut. 2019 Jan 1;244:304–13.

39. Deepthi Y, Shiva Nagendra SM, Gummadi SN. Characteristics of indoor air pollution and estimation of respiratory dosage under varied fuel-type and kitchen-type in the rural areas of Telangana state in India. Sci Total Environ. 2019 Feb 10;650:616–25.

40. Young DBN, Clark ML, Rajkumar DS, Benka-Coker ML, Bachand A, Brook RD, et al. EXPOSURE TO HOUSEHOLD AIR POLLUTION FROM BIOMASS COOKSTOVES AND BLOOD PRESSURE AMONG WOMEN IN RURAL HONDURAS: A CROSS-SECTIONAL STUDY. Indoor Air. 2019 Jan;29(1):130.

41. Tumwesige V, Okello G, Semple S, Smith J. Impact of partial fuel switch on household air pollutants in sub-Sahara Africa. Environ Pollut. 2017 Dec 1;231:1021–9.

42. 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. Environ Pollut. 2017 Jan 1;220:38–45.

43. Holmes HA, Pardyjak ER. Investigation of time-resolved atmospheric conditions and indoor/outdoor particulate matter concentrations in homes with gas and biomass cook stoves in Nogales, Sonora, Mexico. J Air Waste Manag Assoc 1995. 2014 Jul;64(7):759–73.

44. Pollard SL, Williams DL, Breysse PN, Baron PA, Grajeda LM, Gilman RH, et al. A cross-sectional study of determinants of indoor environmental exposures in households with and without chronic exposure to biomass fuel smoke. Environ Health. 2014 Mar 24;13:21.

45. da Silva LFF, Saldiva SRDM, Saldiva PHN, Dolhnikoff M. Impaired lung function in individuals chronically exposed to biomass combustion. Environ Res. 2012 Jan 1;112:111–7.

46. Indoor air pollution and asthma in children at Delhi, India | Kumar | Advances in Respiratory Medicine [Internet]. [cited 2022 Feb 13]. Available from: https://journals.viamedica.pl/advances_in_respiratory_medicine/article/view/42652

47. Awopeju OF, Nemery B, Afolabi OT, Poels K, Vanoirbeek J, Obaseki DO, et al. Biomass smoke exposure as an occupational risk: cross-sectional study of respiratory health of women working as street cooks in Nigeria. Occup Environ Med. 2017 Oct;74(10):737–44.

48. Pratali L, Marinoni A, Cogo A, Ujka K, Gilardoni S, Bernardi E, et al. Indoor air pollution exposure effects on lung and cardiovascular health in the High Himalayas, Nepal: An observational study. Eur J Intern Med. 2019 Mar;61:81–7.

49. Sharma A, Parikh J, Singh C. Transition to LPG for cooking: A case study from two states of India. Energy Sustain Dev. 2019 Aug 1;51:63–72.

50. Kar A, Pachauri S, Bailis R, Zerriffi H. Using sales data to assess cooking gas adoption and the impact of India's Ujjwala programme in rural Karnataka. Nat Energy. 2019 Sep;4(9):806–14.

51. Yadav Y. Women Empowerment through Pradhan Mantri Ujjwala Yojana (PMUY) Scheme in Rajasthan: A Study on Rural Households in Selected Region [Internet].

Rochester, NY: Social Science Research Network; 2020 May [cited 2022 Feb 13]. Report No.: ID 3618802. Available from: https://papers.ssrn.com/abstract=3618802

52. Singh RB, Kumar A. Climate variability and water resource scarcity in drylands of Rajasthan, India. Geoenvironmental Disasters. 2015 Mar 13;2(1):7.
53. Iqbal M. Coronavirus: Rajasthan announces complete lockdown till March 31. The Hindu [Internet]. 2020 Mar 22 [cited 2021 Dec 28]; Available from: https://www.thehindu.com/news/national/other-states/coronavirus-rajasthan-announces-complete-lockdown-till-march-31/article31133432.ece
54. Testing Strategy [Internet]. [cited 2022 Feb 10]. Available from: https://www.icmr.gov.in/cteststrat.html
55. Christopher DJ, Mohan BVM, Singla R, Koul PA. Pulmonary function testing during the COVID-19 pandemicin. Lung India. 2021 Mar;38(Suppl 1):S92.
56. Snapshot [Internet]. [cited 2022 Feb 11]. Available from: https://www.thoracic.org/professionals/clinical-resources/disease-related-resources/pulmonary-function-laboratories.php
57. Ramani VK, Pattankar J, Puttahonnappa SK. Acute Respiratory Infections among Under-Five Age Group Children at Urban Slums of Gulbarga City: A Longitudinal Study. J Clin Diagn Res JCDR. 2016 May;10(5):LC08.
58. Dasgupta S, Huq M, Khaliquzzaman M, Pandey K, Wheeler D. Indoor air quality for poor families: new evidence from Bangladesh. Indoor Air. 2006 Dec;16(6):426–44.
59. Maharana SP, Paul B, Garg S, Dasgupta A, Bandyopadhyay L. Exposure to indoor air pollution and its perceived impact on health of women and their children: A household survey in a slum of Kolkata, India. Indian J Public Health. 2018 Sep;62(3):182–7.
60. Gould CF, Urpelainen J. The Role of Education and Attitudes in Cooking Fuel Choice: Evidence from two states in India. Energy Sustain Dev J Int Energy Initiat. 2020 Feb;54:36–50.
61. Heltberg R. Fuel switching: evidence from eight developing countries. Energy Econ. 2004 Sep 1;26(5):869–87.
62. Muller C, Yan H. Household fuel use in developing countries: Review of theory and evidence. Energy Econ. 2018 Feb 1;70:429–39.
63. Choudhuri P, Desai S. Gender inequalities and household fuel choice in India. J Clean Prod. 2020 Aug 20;265:121487.
64. van der Kroon B, Brouwer R, van Beukering PJH. The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. Renew Sustain Energy Rev. 2013 Apr 1;20:504–13.
65. Masera OR, Saatkamp BD, Kammen DM. From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model. World development. 2000.

66. Ranjan R, Singh S. Household Cooking Fuel Patterns in Rural India: Pre- and Post-Pradhan Mantri Ujjwala Yojana. Indian J Hum Dev. 2020 Dec 1;14(3):518–26.

67. Final Compendium of fact sheets_India and 14 States_UTs (Phase-II).pdf [Internet]. [cited 2022 Feb 1]. Available from: http://rchiips.org/nfhs/NFHS-5_FCTS/Final%20Compendium%20of%20fact%20sheets_India%20and%2014%20States_UTs%20(Phase-II).pdf#toolbar=0&navpanes=0

68. Patel SK, Patel S, Kumar A. Effects of cooking fuel sources on the respiratory health of children: evidence from the Annual Health Survey, Uttar Pradesh, India. Public Health. 2019 Apr;169:59–68.

69. Census of India Website : Office of the Registrar General & Census Commissioner, India [Internet]. [cited 2022 Feb 4]. Available from: https://censusindia.gov.in/2011-common/censusdata2011.html

70. Mishra V. Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe. Int J Epidemiol. 2003 Oct;32(5):847–53.

71. Kumar R, Sharma M, Srivastva A, Thakur JS, Jindal SK, Parwana HK. Association of Outdoor Air Pollution with Chronic Respiratory Morbidity in an Industrial Town in Northern India. Arch Environ Health Int J. 2004 Sep;59(9):471–7.

72. Jindal SK, Aggarwal AN, Gupta D, Agarwal R, Kumar R, Kaur T, et al. Indian study on epidemiology of asthma, respiratory symptoms and chronic bronchitis in adults (INSEARCH). Int J Tuberc Lung Dis Off J Int Union Tuberc Lung Dis. 2012 Sep;16(9):1270–7.

73. Revisedtestingguidelines.pdf [Internet]. [cited 2022 Feb 7]. Available from: https://www.mohfw.gov.in/pdf/Revisedtestingguidelines.pdf

74. आयय, अनन, पररषदन, अनय. Advisory on Strategy for COVID-19 Testing in India. :4.

75. Dasgupta S, Huq M, Khaliquzzaman M, Pandey K, Wheeler D. Who suffers from indoor air pollution? Evidence from Bangladesh. Health Policy Plan. 2006 Nov;21(6):444–58.

76. Ravindra K, Kaur-Sidhu M, Mor S. Transition to clean household energy through an application of integrated model: Ensuring sustainability for better health, climate and environment. Sci Total Environ. 2021 Jun 25;775:145657.

ANNEXURES

Annexure 'A': Ethical Clearance Certificate

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर

All India Institute of Medical Sciences, Jodhpur

संस्थागत नैतिकता समिति

Institutional Ethics Committee

No. AIIMS/IEC/2020/2042 **Date: 01/01/2020**

ETHICAL CLEARANCE CERTIFICATE

Certificate Reference Number: **AIIMS/IEC/2019-20/978**

Project title: **"Effect of biomass fuel use on respiratory morbidities among women and under five children in rural Jodhpur"**

Nature of Project:	**Research Project**
Submitted as:	**M.D. Dissertation**
Student Name:	**Dr.Shaima Abdul Jabbar**
Guide:	**Dr.Neeti Rustagi**
Co-Guide:	**Dr.Suman Saurabh, Dr.Naveen Dutt & Dr. Prawin Kumar**

This is to inform that members of Institutional Ethics Committee (Annexure attached) met on **23-12-2019** and after through consideration accorded its approval on above project. Further, should any other methodology be used, would require separate authorization.

The investigator may therefore commence the research from the date of this certificate, using the reference number indicated above.

Please note that the AIIMS IEC must be informed immediately of:

- Any material change in the conditions or undertakings mentioned in the document.
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research.

The Principal Investigator must report to the AIIMS IEC in the prescribed format, where applicable, bi-annually, and at the end of the project, in respect of ethical compliance.

AIIMS IEC retains the right to withdraw or amend this if:

- Any unethical principle or practices are revealed or suspected
- Relevant information has been withheld or misrepresented

AIIMS IEC shall have an access to any information or data at any time during the course or after completion of the project.

On behalf of Ethics Committee, I wish you success in your research.

Dr. Praveen Sharma

Member Secretary
Institutional Ethics Committee
AIIMS,Jodhpur

Enclose:

1. Annexure I

Page 1 of 2

Basni Phase-2, Jodhpur, Rajasthan-342005, **Website:** www.aiimsjodhpur.edu.in, **Phone:** 0291-2740741 Extn. 3109
Email: ethicscommittee@aiimsjodhpur.edu.in

Annexure ‘B’: Participant information sheet (English)

All India Institute of Medical Sciences Jodhpur, Rajasthan

PARTICIPANT INFORMATION SHEET (PIS)

Title of the Project: Effect of Biomass fuel use on Respiratory morbidities among women and under-five children in rural Jodhpur

Name of the Principal Investigator: Dr. Shaima Abdul Jabbar, Postgraduate student

Department of Community Medicine and Family Medicine

Ph:9400696414

I am doing this study to assess the effect of biomass fuel use on respiratory health of women and under-five children.

For this I will be asking questions to you on symptoms you suffer and the children of your house. And I will do a test on the women of the house.

I would like you to know that this study will not provide you any monetary benefit, but it will help me to generate data for the benefit of the community. You can refuse to answer any question and can withdraw yourself from the study at any point of time.

The data obtained from you and the beneficiaries will be used for the purpose of the study only. All the records will be kept confidential.

For further details or any other query, you may contact the following person who is the Guide for my study:

Dr. Neeti Rustagi
Additional Professor,
Department of Community Medicine & Family Medicine, AIIMS Jodhpur
Mobile No- 800396931

Annexure ‘C’: Participant information sheet (Hindi)

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर, राजस्थान

प्रतिभागी सूचना पत्र

शीर्षक – ग्रामीण जोधपुर में महिलाओं और पांच वर्ष से कम उम्र के बच्चों के बीच श्वसन रुग्णता पर बायोमास ईंधन के उपयोग का प्रभाव

स्नातकोत्तर छात्र - डॉ. शाइमा अब्दुल जब्बार,

स्नातकोत्तर विद्यार्थी,

सामुदायिक चिकित्सा और परिवार चिकित्सा विभाग

फोन: 9400696414

मैं यह अध्ययन महिलाओं और पांच वर्ष से कम उम्र के बच्चों के श्वसन स्वास्थ्य पर बायोमास ईंधन के उपयोग के प्रभाव का आकलन करने के लिए कर रही हूं ।

इसके लिए मैं आपसे श्वसन तंत्र सम्बंधित लक्षणों और आपके घर के बच्चों पर सवाल पूछ रही हूँ। और मैं महिलाओं पर एक परीक्षण करूंगी।

मैं आपको यह बताना चाहूंगी कि यह अध्ययन आपको कोई मौद्रिक लाभ प्रदान नहीं करेगा, लेकिन इससे मुझे समुदाय के लाभ के लिए डेटा उत्पन्न करने में मदद मिलेगी। आप किसी भी प्रश्न का उत्तर देने से इंकार कर सकते हैं और किसी भी समय अपने आप को अध्ययन से हटा सकते हैं।

आपसे प्राप्त डेटा का उपयोग केवल अध्ययन के उद्देश्य के लिए किया जाएगा। सभी रिकॉर्ड गोपनीय रखे जाएंगे।

अधिक जानकारी या किसी अन्य प्रश्न के लिए, आप निम्नलिखित व्यक्ति से संपर्क कर सकते हैं, जो मेरे अध्ययन के लिए मार्गदर्शक है:

डॉ. नीति रुस्तगी

अतिरिक्त आचार्या,

सामुदायिक चिकित्सा एवं परिवार चिकित्सा विभाग,

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर

मोबाइल नंबर- 800396931

Annexure ‘D’: Informed consent form – (English)

All India Institute of Medical Sciences Jodhpur, Rajasthan

Informed Consent Form

Title of Project: Effect of Biomass fuel use on Respiratory morbidities among women and under-five children in rural Jodhpur

Name of Principal Investigator: Dr. Shaima Abdul Jabbar, Postgraduate Resident,

Department of Community Medicine and Family Medicine
Ph:9400696414

Volunteer Identification No.: _____________

I, _____________________________________ S/o or D/o ___________________________

____, give my full, free, voluntary consent to be part of the study titled, “Effect of Biomass fuels on Respiratory morbidities among women and under-five children in rural Jodhpur”, the procedure and nature of which has been explained to me in my own language to my full satisfaction.

I confirm that I have had the opportunity to ask questions. I understand that my participation is voluntary and I am aware of my right to opt out of the study at any time without giving any reason.

I understand that the information collected from me and any of the records about child health services provided by me may be looked at by a responsible individual from AIIMS, Jodhpur or from regulatory authorities. I give permission to these individuals to have access to my records and undertake all study related procedures.

This to certify that the above consent has been obtained in my presence

Date: ….

Place: ……

Signature/Left thumb impression

Witness 1
Signature/Left thumb impression
Name: ….
Date: ……

Witness 2
Signature/Left thumb impression
Name: ….
Date: ……

Annexure 'E': Informed consent form (Hindi)

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर, राजस्थान.

<u>सूचित सहमति प्रपत्र</u>

शीर्षक – ग्रामीण जोधपुर में महिलाओं और पांच वर्ष से कम उम्र के बच्चों के बीच श्वसन रुग्णता पर बायोमास ईंधन के उपयोग का प्रभाव

स्नातकोत्तर छात्र - डॉ. शाइमा अब्दुल जब्बार, स्नातकोत्तर विद्यार्थी,

सामुदायिक चिकित्सा एवं परिवार चिकित्सा विभाग

फोन: 9400696414

पहचान क्रमांक:_________________

मैं,_____________________________पुत्र/पुत्री_____________________________________ __निवासी____,“ ग्रामीण जोधपुर में महिलाओं और पांच वर्ष से कम उम्र के बच्चों के बीच श्वसन रुग्णता पर बायोमास ईंधन के उपयोग का प्रभाव” अध्ययन का हिस्सा बनने के लिए मेरी पूर्ण, नि:शुल्क, स्वैच्छिक अनुमति देता हूँ, जिसकी प्रक्रिया और प्रकृति को मेरी भाषा में पूरी संतुष्टि में मुझे समझाया गया है।

मैं पुष्टि करता हूं कि मुझे प्रश्न पूछने का अवसर मिला है। मैं समझता हूं कि मेरी भागीदारी स्वैच्छिक है और किसी भी कारण के बिना, किसी भी समय अध्ययन से बाहर निकलने के मेरे अधिकार से अवगत हूं।

मैं समझता हूं कि मेरे द्वारा प्रदान की गई जानकारी और मेरे द्वारा प्रदान की गई बाल स्वास्थ्य सेवाओं के बारे में किसी भी रिकॉर्ड को एम्स, जोधपुर के एक जिम्मेदार व्यक्ति या नियामक अधिकारियों से देखा जा सकता है। मैं इन व्यक्तियों को अपने रिकॉर्ड तक पहुंचने और सभी अध्ययन संबंधी प्रक्रियाओं को करने की अनुमति देता हूं।

तिथि: _________________   __________________________
स्थान: _________________   हस्ताक्षर / बाएं अंगूठे का निशान

यह प्रमाणित किया जा रहा है कि उपर्युक्त अनुमति मेरी उपस्थिति में प्राप्त की गई है –

तिथि: _________________   __________________________
स्थान: _________________   स्नातकोत्तर छात्र के हस्ताक्षर

1. गवाह	2. गवाह
_______________________	_______________________
हस्ताक्षर	हस्ताक्षर
नाम ___________________	नाम ___________________
निवासी__________________	निवासी__________________

Annexure ‘F’: Questionnaire– (English)

EFFECT OF BIOMASS FUEL USE ON RESPIRATORY MORBIDITIES AMONG WOMEN AND UNDER FIVE CHILDREN IN RURAL JODHPUR

General information

Mob no:

1. Name of the interviewee
2. Age: …..years
3. Gender of the head of the household a.Male… b.Female

   Relationship to the head of the household……

Place:

Household Socio-economic Characteristics:

4. Total number of people normally living in the house:
5. Total number of women above 15 years

ID	NAME	AGE	EDUCATION	OCCUPATION	SELECTED

6. Family income(monthly)……………. Per capita income…………..

Characteristics of house

7. No. of stories in house …………..
8. No. of rooms in the house ……….
9. Roofing material 1. Tile 2.Thatched 3.Concrete 4.Corrugate iron 5.Others…..
10. Wall construction material

    1. Brick wall 2.Thatched 3.Concrete 4.Corrugate iron 5.Wood 6. Mud 7.Others….
11. Floor construction material

    1. Concrete 2. Brick 3. Wood 4. Mud 5.Bamboo 6.Others…….

Characteristics of kitchen

12. Roofing material 1. Tile 2.Thatched 3.Concrete 4.Corrugate iron 5.Others…..
13. Wall construction material

    1. Brick wall 2.Thatched 3.Concrete 4.Corrugate iron 5.Wood 6. Mud 7.Others….
14. Floor construction material

    1. Concrete 2. Brick 3. Wood 4. Mud 5.Bamboo 6.Others…….

14.Toilet facility 1)septic tank/modern toilet 2)water sealed/slab latrine

3)open pit latrine 4)hanging latrine 5)open defecation 6)others specify

House ventilation related factors

<u>For Kitchen</u>

15. No of walls in the kitchen………………
16. No of windows in the kitchen…………
17. No of doors in the kitchen……………
18. Location of windows/doors allows cross-ventilation? 1. Yes 0. No
19. Vertical surface area of kitchen Length……….. Width .... Height.............

For living area:

20.Vertical surface area of living area: Length…………Width………..Height…………
(Non-kitchen monitor site)

21. Number of walls with opening to the inside of the house:………………
22. If there are two or more openings in the walls, are openings on opposite walls? -1. Yes 0. No

Primary Stove:

23. Stove type: 1.Gas 2.Electric 3.Kerosene 4.MudTraditional 5. MudImproved 6.Others
(specify)………….
24. If mud , what is the fuel used 1. Wood 2. Cowdung 3. Coal 4. Others................
25. Chimney: 1. Yes 0. No
26 . If Yes , what type - 1. Open 2. With Canopy 3. With electrical exhaust

Secondary Stove:

27. Stove type: -1. Gas 2. Electric 3. Kerosene 4. Mud Traditional 5. Mud Improved 6. Others (specify) ……………….
29. If mud, what is the fuel used
1. Wood 2.Cowdung 3.Coal 4.Others
30. Chimney 1.Yes 2.No
31. If yes, what type
1. Open 2.With Canopy 3.With electrical exhaust
32. Is there any seasonal difference in stove choice pattern : 1.Yes 2.No
Please fill in the following table

Stove type	Period 1*	Period 2*	Period 3*
Primary (%)			
Secondary (%)			

*Write the names of the months , eg: November –January ,Poush-Phalgun etc.,in the box immediately below

How many months in a year do you use

a. Primary stove b. Secondary stove

33. Do you use fuel in winters to keep warm 1.Yes 2.No
34. If yes, how many months do you use fuel to keep warm?
35. Do you use biomass fuel smoke to stay mosquito /bug free? 1. Yes 2.No
36.If yes, a) Time b)Type: i. Coil ii. Cow dung iii. Camphor

37.Provide information on person who cooks ?

Type of stove used	Age at which started to cook?	How many days does the person cook in a month?	On a typical day, how often does the person cook?	How many hours per day?
Traditional stove				
Improved stove				

Health Outcomes:

39.Are you currently (in the past 2 weeks) being treated for any medical problems ? a)Yes b)No

1.If yes, please provide information in the following table:

Currently visiting doctor (Yes=1,No=2)	No of visit	How long ago treatment		Problem treated (Wheezing=1, Tightness of chest=2, Shortness of breath=3, Rapid breathing=4, Headache=5, Dizziness=6) Other diseases ,please specify________	Current medication
		Month	Days		

40. Which of the following statement best describes your breathing in the last six months?

Name ID	Code of breathing (Have no trouble breathing=0, Some time trouble breathing =1,regularly have trouble breathing but it never gets completely better=3)

41. Have you ever experienced cough due to smoke from cooking ? 1. Yes 2. No

42. Have you ever experienced difficulty breathing due to smoke ? 1. Yes 2. No

43.Are you aware about Pradhan Mantri Ujjwala Yojana(PMUY) ?

1.Yes 2.No

44.Have you filled form for PMUY ?

1.Yes 2.No

45.Have you received LPG cylinder by PMUY ?

1.Yes 2.No

46.A. Have you replaced any empty LPG cylinder ?

1.Yes 2.No

B. If No , why ?

a. Financial constraints b. Inaccessible refill station c. Lack of supply to residence Other. Specify…

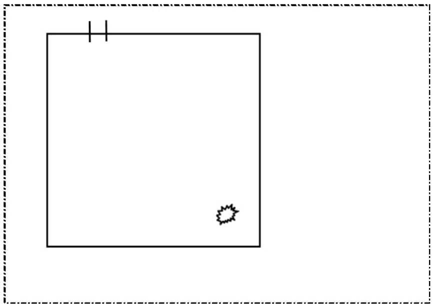
47.

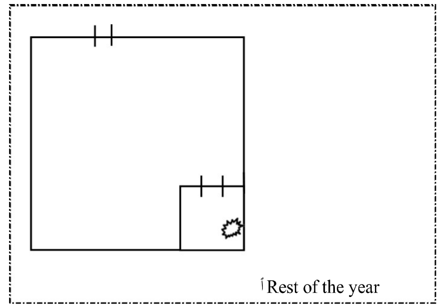
S.NO	Name of child	Age	Gender	Episodes of respiratory illness in past 3 months	Immunisation status (Partially immunised/Completely immunised)

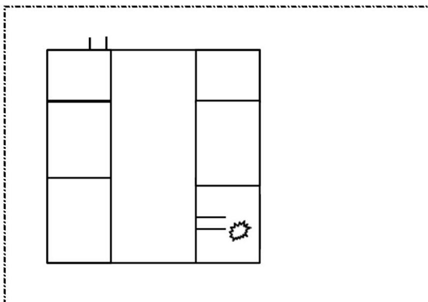
48.Duration of each episode

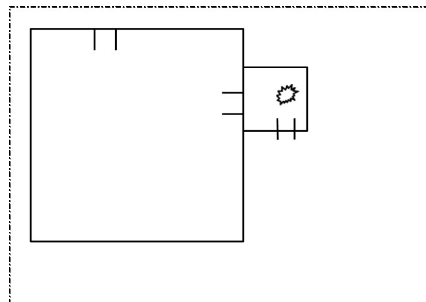
Child s.no	1			2			3		
	</= 3DAYS	4-7 DAYS	>8 DAYS	</= 3DAYS	4-7 DAYS	>8 DAYS	</= 3DAYS	4-7 DAYS	>8 DAYS

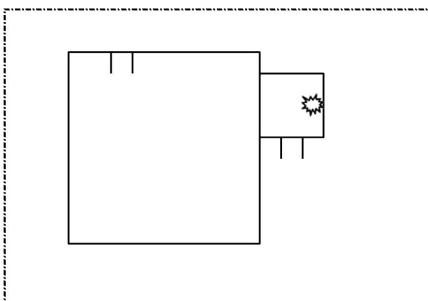
49. Location of kitchen (tick mark the appropriate picture)

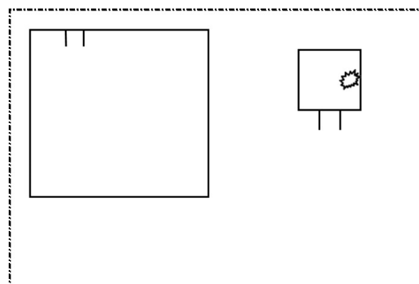


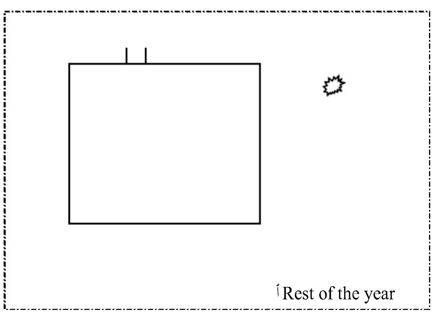


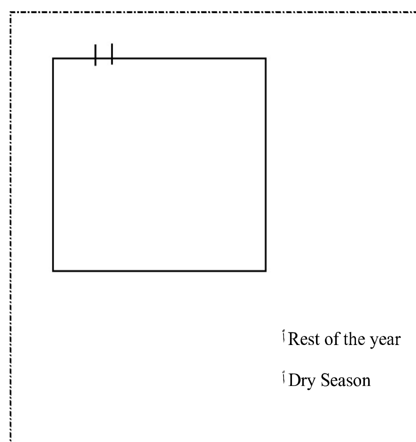












Annexure ‘J’: Questionnaire – (Hindi)

ग्रामीण जोधपुर में महिलाओं और पांच साल से कम उम्र के बच्चों में श्वसन संबंधी बीमारियों पर बायोमास ईंधन के उपयोग का प्रभाव

सामान्य जानकारी

भीड़ संख्या:

1. साक्षात्कारकर्ता का नाम
2. आयु: …..वर्ष
3. घर के मुखिया का लिंग a.पुरुष… b.महिला

घर के मुखिया से संबंध ……….

जगह:

घरेलू सामाजिक-आर्थिक विशेषताएं:

4. घर में सामान्य रूप से रहने वाले लोगों की कुल संख्या:
5. 15 साल से ऊपर की महिलाओं की कुल संख्या

पहचान	नाम	उम्र	शिक्षा	पेशा	चयनित

6. पारिवारिक आय (मासिक)……………. प्रति व्यक्ति आय…………..

घर के लक्षण

7. घर में कहानियों की संख्या ……………..
8. घर में कमरों की संख्या ……….
9. छत सामग्री 1. टाइल 2. छप्पर 3. कंक्रीट 4. नालीदार लोहा 5. अन्य… ..
10. दीवार निर्माण सामग्री

 1. ईंट की दीवार 2. फूस की 3. कंक्रीट 4. नालीदार लोहा 5. लकड़ी 6. मिट्टी 7. अन्य…।

11. तल निर्माण सामग्री

 1. कंक्रीट 2. ईंट 3. लकड़ी 4. मिट्टी 5. बांस 6. अन्य ……।

रसोई की विशेषताएं

12. छत सामग्री 1. टाइल 2. छप्पर 3. कंक्रीट 4. नालीदार लोहा 5. अन्य… ..
13. दीवार निर्माण सामग्री

1. ईंट की दीवार 2. फूस की 3. कंक्रीट 4. नालीदार लोहा 5. लकड़ी 6. मिट्टी 7. अन्य…।

14. तल निर्माण सामग्री

1. कंक्रीट 2. ईंट 3. लकड़ी 4. मिट्टी 5. बांस 6. अन्य ……।

14.शौचालय सुविधा 1)सेप्टिक टैंक/आधुनिक शौचालय 2)पानी सील/स्लैब शौचालय 3)खुले गड्ढे वाला शौचालय

4) हैंगिंग लैट्रीन 5) खुले में शौच 6) अन्य निर्दिष्ट करते हैं ……………।

हाउस वेंटिलेशन संबंधित कारक (लंबाई/चौड़ाई या क्षेत्रों को इकट्ठा करने का सबसे अच्छा तरीका निर्धारित करने की आवश्यकता है)

<u>रसोई के लिए</u>

15. रसोई घर में दीवारों की संख्या………………

16. रसोई घर में खिड़कियों की संख्या ………..

17. रसोई घर में दरवाजों की संख्या ……………..

18. खिड़कियों/दरवाजों का स्थान क्रॉस-वेंटिलेशन की अनुमति देता है? 1. हाँ 0. नहीं

19. रसोई के ऊर्ध्वाधर सतह क्षेत्र की लंबाई ………… चौड़ाई ……… ऊंचाई …………

रहने वाले क्षेत्र के लिए:

20. रहने वाले क्षेत्र का लंबवत सतह क्षेत्र: लंबाई …………… चौड़ाई ………… ऊंचाई ……………

(गैर-रसोई निगरानी साइट)

21. घर के अंदर की ओर खुलने वाली दीवारों की संख्या:………………

22. यदि दीवारों में दो या दो से अधिक उद्घाटन हैं, तो क्या विपरीत दीवारों पर उद्घाटन हैं? -1. हाँ 0. नहीं

प्राथमिक स्टोव:

23. स्टोव का प्रकार: 1.गैस 2.इलेक्ट्रिक 3.केरोसिन 4.मड ट्रेडिशनल 5.मड इम्प्रूव्ड 6.अन्य (उल्लिखित करना)…………।

24. यदि मिट्टी है, तो किस ईंधन का उपयोग किया जाता है 1. लकड़ी 2. गाय का गोबर 3. कोयला 4. अन्य ....

25. चिमनी: 1. हाँ 0. नहीं

26. यदि हाँ, तो किस प्रकार का - 1. खुला 2. चंदवा के साथ 3. विद्युत निकास के साथ

माध्यमिक स्टोव:

27. स्टोव प्रकार: -1। गैस 2. इलेक्ट्रिक 3. मिट्टी का तेल 4. पारंपरिक मिट्टी 5. मिट्टी में सुधार 6. अन्य (निर्दिष्ट करें) ……………।

29. यदि कीचड़ हो तो किस ईंधन का प्रयोग किया जाता है

1. लकड़ी 2. गोबर 3. कोयला 4. अन्य

30. चिमनी 1.हाँ 2.नहीं

31. यदि हां, तो किस प्रकार का

1. खुला 2. चंदवा के साथ 3. विद्युत निकास के साथ

32. क्या चूल्हे की पसंद के पैटर्न में कोई मौसमी अंतर है: 1.हाँ 2.नहीं

कृपया निम्न तालिका भरें

स्टोव प्रकार	अवधि 1*	अवधि 2*	अवधि 3*
मुख्य (%)			
माध्यमिक (%)			

*नवंबर-जनवरी, पौष-फाल्गुन आदि महीनों के नाम तुरंत नीचे के बॉक्स में लिखें।

आप साल में कितने महीने इस्तेमाल करते हैं

ए। प्राथमिक चूल्हा B. माध्यमिक स्टोव

33. क्या आप सर्दियों में गर्म रखने के लिए ईंधन का उपयोग करते हैं 1.हाँ 2.नहीं

34. यदि हाँ, तो आप कितने महीने तक गर्म रखने के लिए ईंधन का उपयोग करते हैं?

35. क्या आप मच्छर/बग मुक्त रहने के लिए बायोमास ईंधन के धुएं का उपयोग करते हैं? 1. हाँ 2.नहीं

36.यदि हाँ, तो क) समय ख) प्रकार: i. कुंडल द्वितीय। गाय का गोबर iii. कपूर

37. खाना बनाने वाले व्यक्ति के बारे में जानकारी दें ?

प्रयुक्त चूल्हे का प्रकार	किस उम्र में खाना बनाना शुरू किया?	एक व्यक्ति एक महीने में कितने दिन खाना बनाता है?	एक सामान्य दिन में, व्यक्ति कितनी बार खाना बनाता है?	प्रति दिन कितने घंटे?
पारंपरिक स्टोव				
बेहतर स्टोव				

स्वास्थ्य परिणाम:

39.क्या आप वर्तमान में (पिछले 2 सप्ताह में) किसी चिकित्सीय समस्या का इलाज करा रहे हैं? ए) हां बी) नहीं

1.यदि हां, तो कृपया निम्नलिखित तालिका में जानकारी प्रदान करें:

		कितने समय पहले शुरू हुआ इलाज	समस्या का इलाज	वर्तमान दवा

वर्तमान में विजिटिंग डॉक्टर (हां = 1, नहीं = 2)	यात्रा की संख्या	महीने	दिन	(घरघराहट = 1, सीने में जकड़न = 2, सांस की तकलीफ = 3, तेजी से साँस लेना = 4, सिरदर्द = 5, चक्कर आना = 6, अन्य रोग, कृपया निर्दिष्ट करें________	

40. निम्नलिखित में से कौन सा कथन पिछले छह महीनों में आपके श्वास का सबसे अच्छा वर्णन करता है?

नाम पहचान	सांस लेने का कोड (सांस लेने में कोई परेशानी नहीं है = 0, कुछ समय सांस लेने में परेशानी = 1, नियमित रूप से सांस लेने में परेशानी होती है लेकिन यह पूरी तरह से बेहतर नहीं होता है = 3)

41. क्या आपको धुएं के कारण खांसी, सांस लेने में कठिनाई या नाक बहने का अनुभव होता है? 1. हाँ 2. नहीं

42. क्या आपको कभी धुएं के कारण सांस लेने में कठिनाई का अनुभव किया है? 1. हाँ 2. नहीं

43. क्या आप प्रधानमंत्री उज्ज्वला योजना (पीएमयूवाई) के बारे में जानते हैं?

1.हाँ 2.नहीं

44.क्या आपने पीएमयूवाई के लिए फॉर्म भरा है?

1.हाँ 2.नहीं

45.क्या आपको पीएमयूवाई द्वारा एलपीजी सिलेंडर प्राप्त हुआ है?

1.हाँ 2.नहीं

46.ए. क्या आपने कोई खाली एलपीजी सिलेंडर बदला है?

1.हाँ 2.नहीं

बी. यदि नहीं, तो क्यों?

क.वित्तीय बाधाएं ख. दुर्गम रिफिल स्टेशन सी. आवास के लिए आपूर्ति की कमी अन्य। निर्दिष्ट करें ……..

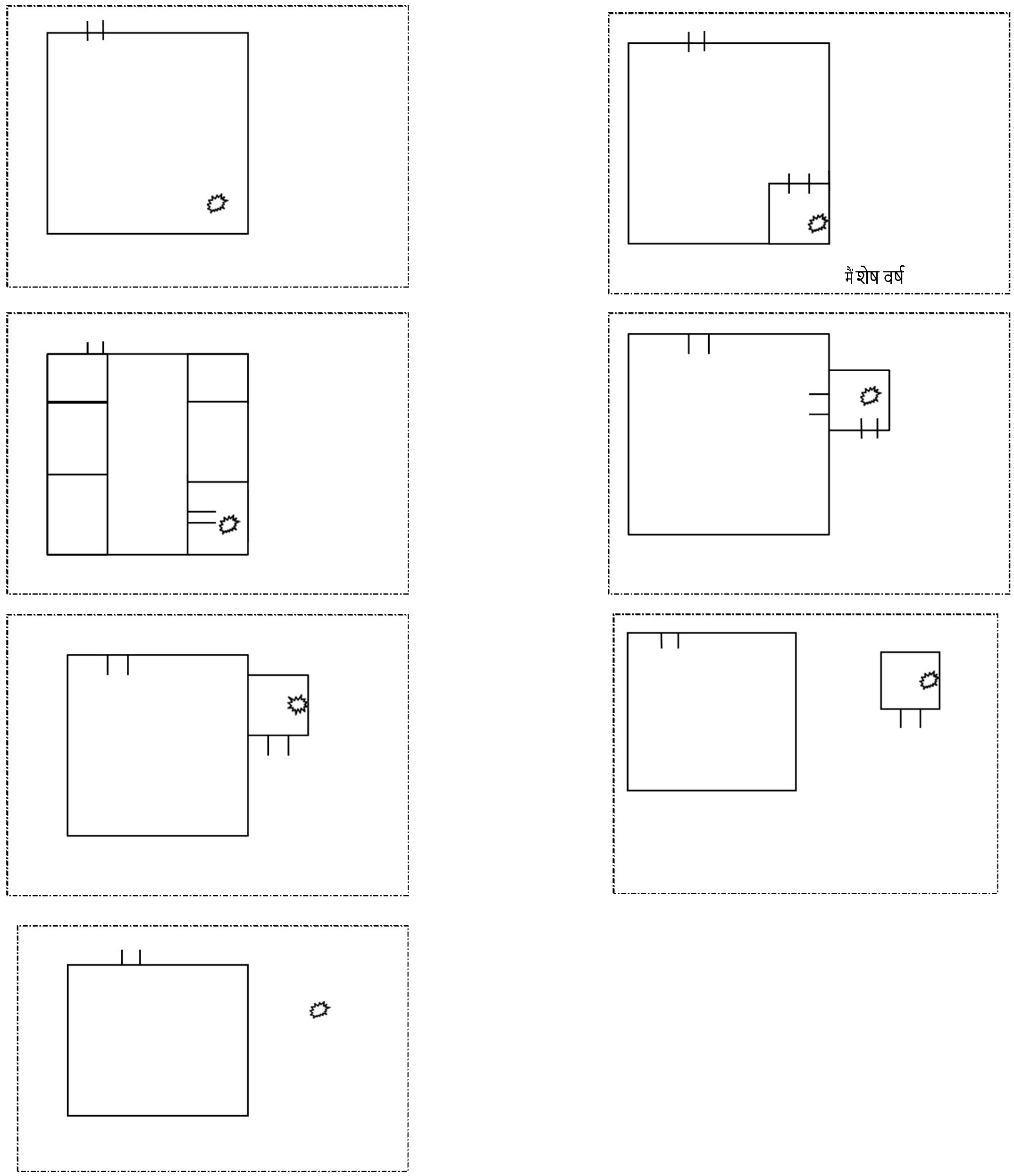
47.

क्रमांक	बच्चे के नाम	उम्र	लिंग	पिछले 3 महीनों में सांस की बीमारी के एपिसोड	टीकाकरण की स्थिति (आंशिक रूप से प्रतिरक्षित

48.प्रत्येक एपिसोड की अवधि

बच्चा	1			2			3		
	</= 3 दिन	4-7 दिन	>8 दिन	</= 3 दिन	4-7 दिन	>8 दिन	</= 3 दिन	4-7 दिन	>8 दिन

50. रसोई का स्थान (उपयुक्त चित्र पर सही का निशान लगाएँ



Annexure K: Snapshots from the study area