
**“MATERNAL EXPOSURE TO INDOOR AIR
POLLUTION AND BIRTH OUTCOMES IN RURAL
AREA - A LONGITUDINAL STUDY”**

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SEPTEMBER / OCTOBER 2025

**Maternal exposure to indoor air pollution and birth outcomes in rural area
- a Longitudinal study**

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LIST OF ABBREVIATIONS USED

S. No.	Abbreviations	Expansions
1.	IAP	Indoor Air Pollution
2.	PM	Particulate Matter
3.	WHO	World Health Organization
4.	UNICEF	United Nations International Children's Emergency Fund
5.	IEA	International Energy Agency
6.	IRENA	International Renewable Energy Agency
7.	UNSD	United Nations' Statistics Division
8.	CPCB	Central Pollution Control Board
9.	LBW	Low Birth Weight
10.	$\mu\text{g}/\text{m}^3$	microgram per cubic millimetre
11.	AAP	Ambient Air Pollution
12.	HAP	Household Air Pollution
13.	SES	Socio-Economic Status
14.	PHC	Primary Health Centre
15.	CO_2	Carbon Dioxide
16.	SO_2	Sulphur Dioxide
17.	PTB	Pre-Term Birth
18.	SGA	Small for Gestational Age
19.	SDGs	Sustainable Developmental Goals
20.	BMI	Body Mass Index
21.	LSCS	Lower Section Cesearean Section
22.	NVD	Normal Vaginal Delivery
23.	LPG	Liquified Petroleum Gas
24.	CO	Carbon Monoxide
25.	BC	Black Carbon
26.	OR	Odds Ratio
27.	UOR	Unadjusted Odds Ratio
28.	SD	Standard Deviation
29.	AOR	Adjusted Odds Ratio

30.	CI	Confidence Interval
31.	gm	Gram
32.	Hb	Heamoglobin
33.	MW	Mann-Whitney
34.	MC	Monte-Carlo
35.	BG	Bramh Govind
36.	HAPIN	Household Air Pollution Intervention Trial
37.	RR	Relative Riak
38.	CPI	Consumer Price Index
39.	mg	milligram
40.	dL	deci Litre
41.	JNMC	Jawaharlal Nehru Medical College
42.	KAHER	KLE Academy of Higher Education and Research
43.	IEC	Institutional Ethics Committee
44.	%	Percentage
45.	=	Equal to
46.	>	Greater than
47.	<	Less than
48.	\geq	Greater than or equal to
49.	\leq	Less than or equal to

ABSTRACT

“MATERNAL EXPOSURE TO INDOOR AIR POLLUTION AND BIRTH OUTCOMES IN RURAL AREA - A LONGITUDINAL STUDY”

Background:

Indoor air pollution (IAP) is a consistently emerging global health concern. Specifically, it has deteriorating health effects in both the mother and the newborn, if there is maternal exposure to indoor air pollution. Use of biomass as cooking fuel is a major constituent that could lead to IAP, causing many adverse birth outcomes. The estimation of LBW is 15% to 20% of all births worldwide and globally, 13.9 stillbirths for every 1,000 population are recorded. PM_{2.5}, one of the most hazardous among numerous indoor air pollutants, was measured to see the extent of IAP and its effects on birth outcomes.

Objective:

To determine the association of maternal exposure to indoor air pollution and birth outcomes in rural area.

Methods:

A longitudinal study was conducted from April 2023 to March 2024. 264 pregnant women were enrolled as study participants. Socio-demographic, household and cooking characteristics of the participants were collected using pretested questionnaire. ANOVA, t-test and Multiple regression analysis was utilized. PM_{2.5} concentrations for IAP were measured for 24 hours in the household of every participant, using a standard Air Quality monitor.

Results:

Out of the 264 study participants, nearly half of the participants (46.59%) aged between 25 - 30 years, majority (82.95%) were housewives and 38.26% belonged to socio-economic class III. More than half (56.06%) of the participants preferred both liquid petroleum gas and wood for cooking purposes. 79.1% of the participants were exposed to IAP and, 14.3% of the total study participants experienced adverse birth outcomes. More than half (56.82%) of the study participants were living in households with PM_{2.5} concentrations exceeding 80 µg/m³ or more. Prolonged duration of cooking, and the mean 24-hour concentrations of PM_{2.5} were associated with adverse birth outcomes. It was revealed that the participants were 2.1417 times more likely to have adverse birth outcomes with unit increase in total time spent of cooking. Factors such as previous bad obstetric history, presence of dampness in the household, having a household without cross-ventilation, area of cooking and exposure to IAP did not show significant association with adverse birth outcomes. For every increase in 10 µg/mm³ of PM_{2.5} concentration, the chances of having an adverse birth outcome increased by 1.07892 times and, with every increase in 10 µg/m³ of maternal PM_{2.5} exposure, there was a reduction in the birth weight of the new-born by 6.623 gm.

Conclusion:

79.1% of the participants were exposed to indoor air pollution and 14.3% of the participants had adverse birth outcomes. After adjusting for maternal characteristics, adverse birth outcomes were influenced by total duration of cooking. It was found that there are several contributing factors to IAP and maternal exposure to IAP is a major risk factor for adverse birth outcomes.

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Introduction:

Indoor air pollution has become a scare to the present world. It has emerged as one of the disturbing global issues, concerning living population just as equally as any type of pollution. Indoor air pollution is a major constituent of pollution, evidently intervening and causing serious health disorders among those, who are exposed to it. Contrary to outdoor air pollution, indoor air pollution is more insidious because it remains persistent within any enclosed space for extended duration of time and therefore is considered more hazardous to the individuals who are exposed to indoor air pollutants. Indoor air pollution is defined as, the contamination of indoor air by harmful chemicals and usage of other materials such as inefficient fuels or technologies in the home.¹ It is evident that even though every individual of a household, exposed to the indoor air pollutants, is at a heightened risk but, since women tend to spend a lot of time in their households, they are more prone to indoor air pollution (IAP) than the rest. They are particularly a vulnerable population in developing countries like India. Pregnant women should be specifically taken into consideration, as they are even more prone to hazards of IAP. The period of pregnancy is significantly marked by physiological changes altering both maternal and foetal health, and thus can be influenced by environmental factors. During the critical stages of development, the foetus is susceptible to any environmental stressors, as the placental barrier is not always effective against pollutants and as a result these pollutants reach the fetus. This implicates that maternal exposure to the indoor air pollutants can cause pathological changes which can lead to deteriorating conditions in both the mother and the fetus. So, other than the health effects the exposed pregnant women could incur, they are at an additional risk of adverse birth outcomes such as low birth weight (LBW), preterm births, stillbirths and abortions when they are exposed to IAP during pregnancy.²

Globally, 13.9 stillbirths for every 1,000 population have been recorded in 2022, and over one-third of these still-births were reported from India.^{3,4} Conditions in newborns such as LBW and preterm births are strong risk factors for neonatal mortality, neonatal morbidity or even infant mortality and infant morbidity.⁵ Sometimes, suppose the affected newborns surpass the phase of infancy, LBW and preterm births can also cause lifelong consequences during their childhood. The estimation of LBW is 15% to 20% of all births worldwide which constitute to more than 20 million births a year.^{5,6} The combined estimates report of United Nations International Children's Emergency Fund and the World Health Organization (UNICEF-WHO) estimate that low birth weight affects one in every seven newborns worldwide.^{7,8} Low birth weight continues to be a health burden all over the world implicating short term and long term consequences. Whereas, WHO reported that preterm birth complications happen to be a major risk factor for mortality among children under 5 years of age, with an estimation of 13 million preterm births a year, globally.⁹ In this scenario, India and the rest of South Asia contributes to 20% of the world's preterm births. According to a recent report by UNICEF, one in every 10 live births is a preterm birth and preterm births are one of the leading causes of neonatal mortality.¹⁰

The extent of indoor air pollution during antenatal period has become a growing concern globally. Research has demonstrated that, maternal exposure to indoor air pollutants, at any time during the pregnancy period independent of the trimester, can be associated with not only negative outcomes like LBW, preterm births, abortions but also developmental delays in children. In addition to this, maternal exposure to unhealthy indoor air with poor air quality standards can increase the likelihood of respiratory pathologies in both the mother and the newborn.

Impacts of indoor air pollution evidently cause pathological changes during the entire antenatal period. These impacts have been advocated through all the three trimesters of

pregnancy. For instance, early stage of pregnancy can be a particularly sensitive period during which exposure to pollutants can disrupt organogenesis or the initial phases of fetal development. Similarly, chronic exposure to indoor air pollutants over the course of pregnancy can lead to different type of severe adverse outcomes such as low birth weight, preterm births and various pathologies in newborns that might manifest later in life.

There are numerous indoor air pollutants that can cause indoor air pollution and Particulate matter (PM) is one of the most hazardous among them. The air pollutant PM_{2.5}, defined as, fine particulate matter with diameter of 2.5 µm or less is directly related to indoor air pollution and has been observed to be a potent indicator of indoor air pollution.¹¹

The sources which produce PM_{2.5} ultimately leading to IAP are bio-aerosols, combustion of fuels used for cooking, materials used for construction and to an extent inflow of outdoor air pollution.^{12, 13} Solid fuels specifically which come under unhealthy cooking practices are biomass or coal. Biomass fuels could be wood, animal dung, agricultural residues or straw hay. Factors which generate higher levels of indoor air pollutants, other than biomass are, ill-ventilated households, over-crowding, unhygienic maintenance of households or surroundings, paints, lacquers, paint strippers, pesticides, mosquito repellents, incense sticks, dry-cleaning fluids and home furnishes.¹² Kerosene even though a better alternative for solid fuels, still emits substantial amounts of indoor air pollutants and hence considered unsafe. Around 2.1 billion people worldwide which amounts to around a third of the global population, prefer solid fuels for cooking.¹³

According to WHO, the safer choices of cooking fuel are piped natural gas, electricity, liquid petroleum gas (LPG), biogas, solar power and alcohol or ethanol.¹⁴ These fuels account to better indoor air quality when compared to biomass and other solid fuels. Additionally, they lead to permissible and acceptable levels of indoor air pollutants which do

not cause any harm to health, given there are no other possible factors causing indoor air pollution in the household. Indian national standards of 24-hour average indoor PM_{2.5} concentration is considered as 40 µg/m³.¹⁵ And majority of the Indian population living in either rural or urban areas, have crossed this acceptable limit due to various indoor activities and lifestyle preferences which have the chances of emitting PM_{2.5}.¹⁶ It has been reported that more than 40% of Indian households still rely on solid fuels like wood, agricultural byproducts, dung, and charcoal for cooking.¹⁷

Maternal exposure to indoor air pollution poses a significant risk to maternal and fetal health. This issue needs to be addressed using a multifaceted approach, involving education of communities, lifestyle modifications, healthy practices and interventions aimed at improving indoor air quality, such that vulnerable population can be protected by mitigating exposure. Few studies have attempted to correlate IAP to detrimental effects on pregnant women, ranging from obstetric complications to adverse birth outcomes. But previous research which highlights relation between IAP and adverse outcomes of pregnancy is inadequate. Hence, it is necessary to contribute evidence to the available literature and as an added benefit, the present study utilized 24-hour measurements of household PM_{2.5} concentrations. Ultimately, to aspire healthier pregnancies and to safeguard maternal and fetal health in future, the present study was planned to determine the association between maternal exposure to indoor air pollution and adverse birth outcome.

Objective:

To determine the association of maternal exposure to indoor air pollution and birth outcomes in rural area.

Review of Literature:

A study was conducted in 2021 utilizing the data availed from the National Family Health Survey - V (NFHS - V), among 93,721 full-term newborns to investigate the comprehensive effects of household air pollution and low birth weight, mean birth weight and size immediately after birth, in India. Results indicated that children, under 5 years of age, who were born in households that used clean cooking fuels had 80 gm [2877 gm, 95% CI: 2876 - 2877] higher birth weight when compared to the unsafe cooking fuels using households [2797 gm, 95% CI: 2796-2798] and households using unclean cooking fuels without a separate kitchen [2779 gm, 95% CI: 2778-2780] had 59 gm and 98 gm lower mean birth weight, when compared to the households using unclean cooking fuels with a separate kitchen. The study concluded that transition is necessary to clean fuels from unclean fuels and a separate kitchen provision should be encouraged such that a decrease in any kind of maternal exposure to household air pollution can be achieved and thereby, adverse birth outcomes.¹⁹

A prospective study was conducted among 100 low birth weight newborns in the year 2023 from a tertiary health centre in India to study the maternal factors influencing low birth weight, to find out the prevalence of low birth weight and to analyze and correlate the neonatal outcomes of low birth weight with maternal etiological factors. The study results found that maternal factors such as anaemia, hypertension, inadequate antenatal care, and lower socioeconomic status were observed to be associated with low birth weight significantly in newborns and furthermore, clinical interventions, including supplementation of required amount of iron, properly adequate maternal nutrition, management of hypertensive disorders of pregnancy as and when required, and awareness creation through

public education on the importance of antenatal care, were shown to positively impact neonatal outcomes. The study concluded that early identification of all possible risk factors and prompt interventions are essential in reducing the incidence of low birth weight and related neonatal mortality. Additionally, regular antenatal care visits are critical for the early detection of risk factors such as anaemia, poor nutrition, hypertension, maternal tobacco and nicotine use, and for implementing preventive strategies.²⁰

A cross-sectional study was utilized in 2022 in Africa using the standard Demographic and Health Surveys data between 2005 and 2021 among 1,31,594 births to assess the associations between maternal PM_{2.5} exposure and low birth weight and preterm births. The study results revealed that, an interquartile range of 33.9 µg per m³ increase in PM_{2.5} during pregnancy was linked to higher odds in low birth weight cases [OR = 1.28; 95% CI: (1.23, 1.34)] and preterm births [OR = 1.08; 95% CI: (1.01, 1.16)] out of a total of 13,214, accounting to 10% of low birth weight cases and 4,377, constituting to 3.3% of preterm births that were identified. In Western Africa and Southern Africa countries, there were also noteworthy correlations between PM_{2.5} and preterm births. In contrast, PM_{2.5} was found to be associated to low birth weight in all subgroups, with stronger correlations seen in female infants. Additionally, older people who lived in urban areas had a higher correlation between PM_{2.5} and preterm births. Significant correlations between maternal particulate matter PM_{2.5} exposure and elevated risks causing low-birth-weight newborns and preterm births were found in this study, and results such as these should be taken into account to support air quality control measures that avoid birth outcomes in lower- and middle- income countries.²¹

A systematic review and meta - analysis was performed to assess the link between indoor air pollution exposure and negative pregnancy outcomes in low- and middle-income countries in which, the analysis included 2,120,228 participants from 30 studies published between 2000 and 2023. The study findings revealed a significant pooled association between exposure to indoor air pollution and at least one adverse pregnancy outcome, with an overall risk increase of 15.5% (95% CI: 12.6, 18.5) and the analysis also found considerable heterogeneity ($I^2 = 100\%$; $p < 0.001$). Specifically, exposure to indoor air pollution was linked to a 23.7% higher risk of small-for-gestational-age births (95% CI: 8.2, 39.3) and a 17.7% increased risk of low birth weight (95% CI: 12.9, 22.5). Further analysis identified several key factors associated with adverse pregnancy outcomes, including exposure to biomass fuel (OR = 1.16; 95% CI: 1.12–1.2), particulate matter (OR = 1.28; 95% CI: 1.25–1.31), and kerosene (OR = 1.38; 95% CI: 1.09–1.66). The study concluded that more than one in seven pregnant women exposed to indoor air pollution experienced at least one negative pregnancy outcome. Moreover, it emphasized that exposure to particulate matter, biomass fuel, and kerosene were significant determinants of these adverse outcomes. The findings call for urgent and comprehensive health interventions to mitigate the risks associated with indoor air pollution and improve maternal and fetal health outcomes.²²

A community based cross-sectional study was conducted in Karnataka between 2018 and 2021 among 632 women to know the pattern of fuel used for the purpose of cooking in households and also to determine the association between different types of fuel used according to socio-demographic factors and characteristics and health conditions, both normal or underlying pathologies, of the research study participants. Results indicated that 72.5% of the households that used biomass, 67.2% used both biomass and liquid petroleum gas and 5.2% preferred only biomass as fuel for cooking. The selection of biomass among

the 13 women exposed to it was correlated with age, occupation, socioeconomic class, and reading level ($p = <0.001$), and those exposed to biomass were linked to self-reported cardiovascular symptoms [OR: 6.07; 95% CI: (1.88, 19.67)], respiratory symptoms [OR: 5.04; 95% CI: (2.52, 10.07)], dermatological symptoms [AOR: 3.67; 95% CI: (1.07, 12.55)], and ophthalmic disorders [AOR: 3.85; 95% CI: (1.79, 8.29)], with unfavourable health outcomes during pregnancy [AOR: 2.45; 95% CI: (1.08, 5.57)]. According to the study's findings, two-thirds of women who preferred biomass as fuel for cooking reported feeling better about their health, and identifying dangerous air pollutants in pregnant women's homes is crucial to preventing any unfavourable obstetric outcomes.²³

A cross-sectional study was carried out 385 mothers from rural communities' maternity clinics of Sri Lanka from 2019 to 2020 to investigate and evaluate the impact of biomass energy source or fuel preferred for cooking purpose on adverse fetal growth outcomes, in Sri Lanka. The findings also theorised the endocrine metabolism disruption for gestational age malnourishment and gestational age, revealed that exposure to biomass cooking fuels during pregnancy was associated with an increased risk of low birth weight [AOR: 2.74 (95% CI: 1.08, 6.96)] and intrauterine growth restriction [AOR: 1.87 (95% CI: 1.03, 3.41)] when compared to the use of clean energy sources. Additionally, the risk of low birth weight was higher with traditional biomass stoves compared to improved biomass stoves [AOR: 3.23 (95% CI: 1.17, 8.89)], and with the use of biomass in kitchens without a chimney compared to those with a chimney [AOR: 4.63 (95% CI: 1.54, 13.93)] and similar statistical findings were observed in case of newborns with intrauterine growth restriction. The study concluded that exposure to air pollution inside the household or an enclosed space (HAP) from biomass fuel use during pregnancy is associated with an elevated risk of low

birth weight and in case of newborns intrauterine growth restriction, with the risk being further amplified by the use of traditional biomass stoves and kitchens lacking chimneys.²⁴

A meta-analysis of 19 studies in 2021 was utilized to evaluate the effect of household air pollution and all the adverse pregnancy outcomes. The results showed that indoor combustion of solid fuels brought about a 86.43 g (95% CI: 55.49, 117.37) reduction in birth weight, with also a 35% [EE: 1.35, (95% CI: 1.23, 1.48)] increased risk of low birthweight along with a 29% [EE: 1.29, (95% CI: 1.18, 1.41)] increased risk of stillbirths and the study concluded that solid fuel combustion inside the household increases the risk of various adverse pregnancy outcomes and there is a necessity to access clean household energy methods to combat and overcome indoor air pollution so as to further overcome the adverse effects attained from indoor air pollution, on health.²⁵

A prospective cohort study was conducted in 2023 among 214 participants included from the maternal and developmental risks from environmental and social stressors (MADRES) study cohort to investigate the relationship between exposure six major chemically derived sources of individual PM_{2.5} during the third trimester of pregnancy and infant birth weight, and to determine and identify whether specific elements within these source mixtures contributed to the adverse health effects. The results significantly identified that mean birth weight was 3295.8 gm (SD: 484.1) and mean PM_{2.5} exposure was 21.3 (SD: 14.4) µg/m³, and a 99.2 g decrease in birth weight (95% CI -197.7, -0.6) was observed with each standard deviation increase in the mass contribution of the fresh sea salt source and sea salt that was aged, was linked with a 70.1 gm reduction in birth weight (95% CI- 141.7, 1.4). Additionally, sodium, magnesium, and chlorine were linked to lower birth weight, with these associations remaining significant after adjusting for PM_{2.5} mass. The study concluded

that major sources of individual PM_{2.5}, including both fresh sea salt and aged sea salt, were negatively linked with birth weight. The most pronounced effects on birth weight were observed with sodium and magnesium. Furthermore, the impact of crystal and fuel oil sources varied by sex of the infant, showing negative associations in boys and positive associations among female infants.²⁶

A systematic review and meta - analysis was carried out in 2023 utilizing 26 articles from three databases which were PubMed, Scopus and Science Direct in Thailand to investigate the causative pathologies of exposure to PM_{2.5} on the risk of low birth weight and to provide a theoretical and comprehensive analysis of the critical periods of exposure and their effects on fetal development through the examination of data spanning multiple trimesters. Results indicated that a significant relationship was found between PM_{2.5} exposure and low birth weight in both the first trimester and second trimester ($p < 0.001$), [OR:1.05, 95% CI: 1.00–1.09] and there was no analytical difference within the three trimesters that was determined statistically ($p = 0.704$) and the study demonstrated a continuous impact of PM_{2.5} on fetal development at every stage of pregnancy, showing a consistent association between prenatal exposure to PM_{2.5} and a heightened risk of low birth weight. The most significant effects were noted during the first and second trimesters, emphasizing the crucial periods of fetal development where exposure may have the most pronounced consequences.²⁷

A meta-analysis of 84 cohort studies was carried out in 2023 was to evaluate the impact of air particulate on pregnancy outcomes such as preterm birth, moderate preterm birth, very preterm birth, extreme preterm birth, term low birth weight (TLBW), term birth weight, stillbirth and small for the respective gestational age. The results determined that for

every 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ exposure, there was a 2.7% - 9.3% increase in preterm birth during second and third trimesters, a 10.5% - 19.3% increase of preterm birth risk in entire pregnancy and in first and second trimesters, a 8.3% and 10.1% increase of term- low birth weight and SGA risk in entire pregnancy, a 25.6% and 10.1% increase of SB in entire pregnancy and second trimester. Also, there was a 13.274 gm and 4.916 gm reduce of Total birth weight during entire pregnancy and second trimester respectively and every 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} exposure was associated with 12.1% and 2.6% increase of preterm birth risk in entire pregnancy and third trimester; 48.9% and 5.0% increase of moderate preterm birth risk in entire pregnancy and second trimester; 14.4% and 10.3% increase of very preterm birth risk in first and third trimesters; 2.9% increase of extremely preterm birth risk in second trimester; 1.5% - 3.8% and 2.9% - 3.7% increase of term- low birth weight and SGA risk in entire pregnancy, exclusively first trimester, second trimester; 7.0% increase of SB risk in third trimesters; and 4.537 gm in first trimester and 5.263 gm reduction of Total birth weight in second trimester respectively. The study concluded that elevated mean annual concentrations of PM were linked to a higher incidence of severe adverse pregnancy outcomes, including preterm births, intrauterine growth restriction infants, and stillbirths and conversely, lower mean annual PM concentrations were associated with a reduction in total birth weight and an increased risk of very low birth weight.²⁸

A meta - analysis done in 2021, was implemented across 204 countries, including 124 articles, to estimate the global burden of low birth weight and preterm birth and their possible impact on reduced birth weight and gestational age, attributable to ambient and indoor $\text{PM}_{2.5}$ pollution. The results revealed pooled estimates indicating a 22 gm (95% UI: 12, 32) reduction in birth weight, an 11% increased risk of low birth weight (OR:1.11, 95% UI: 1.07, 1.16), and a 12% increased risk of preterm birth (OR:1.12, 95% UI: 1.06, 1.19) per

10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$. Additionally, a global population-weighted mean reduction of 89 grams (95% UI: 88, 89) in birth weight and 3.4 weeks (95% UI: 3.4, 3.4) in GA in 2019 was attributable to total $\text{PM}_{2.5}$ exposure. Globally, an estimated 15.6% (95% UI: 15.6, 15.7) of all low birth weight and 35.7% (95% UI: 35.6, 35.9) of all preterm birth cases were attributed to total $\text{PM}_{2.5}$, corresponding to 2,761,720 (95% UI: 2,746,713 to 2,776,722) and 5,870,103 (95% UI: 5,848,046 to 5,892,166) infants in 2019, respectively. Approximately one-third of the total $\text{PM}_{2.5}$ burden for low birth weight and preterm birth was attributed to ambient exposure, with household air pollution (HAP) being more prevalent in low-income countries. The study concluded that ambient and indoor $\text{PM}_{2.5}$ exposure were significantly associated to reduced birth weight and shorter gestational age, which further contribute to increased neonatal and infant mortality, especially in low- and middle-income countries.²⁹

A cohort study was executed between 2013 to 2020 among 760 mother-live births cohort in South Africa to identify maternal socio-demographic and antenatal factors that might be associated with preterm births and lesser birth weight among of South African low socio-economic communities. Results found that out of the total 760 births 16.4% were preterm births and 13.5% were low birth weight and delivery through caesarean section had an increased odds of having preterm birth babies [AOR: 1.7; (95% CI: 1.1, 2.7)] low birth weight babies [AOR: 1.7; (95% CI: 1.1, 2.7)] when compared to normal vaginal deliveries and the odds of having preterm babies increased in mothers with age >30 years [AOR: 1.8; (95% CI: 1.1, 2.9)] and who were current smokers [AOR: 2.7; (95% CI: 1.3, 5.8)]. Study participants with high BMI (25.0 - 29.9 kg/m^2), showed an effect on preterm births [AOR: 0.5; (95% CI: 0.3, 0.9)] and low birth weight [AOR: 0.5; (95% CI: 0.3–0.8)], and participants with obese BMI (> 30 kg/m^2) had an effect on preterm births [AOR: 0.5; (95% CI: 0.3, 0.9)] and low birth weight [AOR: 0.4; (95% CI: 0.2, 0.7)] but maternal HIV

infection effect on preterm births [AOR: 1.4] and low birth weight [AOR: 1.2] and history of sexually transmitted infections effect on preterm births [AOR: 2.7] and birth weight [AOR: 4.2] were found to be non-significant statistically. The study concludes that maternal risk factors for preterm births are cigarette smoking, middle age (> 30 years) pregnancies and low BMI whereas maternal HIV infection and other sexually transmitted infections showed a trend towards being risk factors for preterm births and low birth weight outcomes.³⁰

A cohort study was carried out among 18,863 births during 2019 in China to investigate the associations of Particulate Matter with both fetal growth in utero and birth weight in the area with relatively high air pollution, using the ultrasonography and birth information from the recorded birth cohort. Results indicated that with every 10 $\mu\text{g}/\text{m}^3$ raise in $\text{PM}_{2.5}$ and PM_{10} concentrations, there was a lower estimated birth weight Z-score [-0.031, 95% CI: -0.047, -0.016 and -0.030, 95% CI: -0.043, -0.017] and an elevation in 10 $\mu\text{g}/\text{m}^3$ in $\text{PM}_{2.5}$ concentrations was revealed to be associated to lower birthweight with Z-score [-0.035, (95% CI: -0.061, -0.010)] and higher risk of low birth weight [OR: 1.240, (95% CI: 1.019, 1.508)] and these results remained the same in co-pollutant models and sensitivity analyses. The study concluded that there was an an inverse association between $\text{PM}_{2.5}$ and fetal growth in utero and the association between $\text{PM}_{2.5}$ and fetal growth persisted from pregnancy to birth, supporting that further actions towards controlling air pollution are profoundly recommended for promoting health from early-life.³¹

A prospective cohort study was utilized in 2020 among 1,626 pregnant women in Ghana to investigate the potential associations between exposure to various fuel types for cooking and various birth outcomes in Northern region of Ghana. The results revealed that

the mean maternal age at delivery was 27.3 years (SD = 5.2). Mothers who used charcoal for cooking had a 1.4- fold increased risk of preterm birth (95% CI: 1.04, 2.05) compared to those using other cooking methods, after adjusting for potential confounding factors. In contrast, the use of firewood was associated with a 1.1- fold increased risk of preterm birth (95% CI: 0.83, 1.69). Additionally, mothers who used charcoal had a 1.3- fold increased risk of delivering a low birth weight infant (95% CI: 0.45, 3.97), while those using firewood exhibited a 1.2- fold increased risk (95% CI: 0.41, 3.71). The study also found that infants of mothers who used charcoal had a 1.7- fold increased risk of being intrauterine growth restriction (SGA) (95% CI: 0.52, 5.65), with a similar 1.7- fold increase in risk for those whose mothers used firewood (95% CI: 0.49, 5.92), after adjusting for BMI at the first visit and anaemia. Furthermore, charcoal use was linked to a 1.8- fold increased risk of perinatal mortality (95% CI: 0.29, 11.64), while firewood use showed a 2.0- fold increased risk (95% CI: 0.31, 13.04), after controlling for potential confounders. Although a significant association between charcoal use and preterm birth was observed, no significant associations were found between charcoal or firewood use and low birth weight, SGA, or perinatal mortality when compared to gas or electricity use. These findings suggest that cooking with charcoal or firewood may have potential health implications for pregnancy outcomes.³²

A recent observational study conducted as part of the Household Air Pollution Intervention Network (HAPIN) trial explored the relationship between exposure to fine particulate matter PM_{2.5}, carbon monoxide (CO), and black carbon (BC) during pregnancy and its effects on birthweight, between 2018 and 2021, spanning several countries, including India, Guatemala, and Peru, and included 3,000 pregnant women and the aim was to assess how exposure to various air pollutants, commonly produced by solid fuel cooking, could

influence birth outcomes, specifically birthweight. The results found that each doubling of PM_{2.5} levels resulted in an average reduction in birthweight by approximately 50 gm and exposure to CO was associated with a decrease of around 110 gm in birthweight, higher levels of black carbon also correlated with a reduction of approximately 95 gm and after adjusting for multiple confounders, such as maternal age, (BMI) body mass index, smoking, and socioeconomic factors, ensuring that the relationships observed were independent of these variables, PM_{2.5}, were linked to adverse pregnancy outcomes, with lower birthweights leading to increased risks of neonatal complications and the findings underscore the importance of addressing household air pollution in order to mitigate its impact on maternal and child health. The study concluded that reducing exposure to pollutants like PM_{2.5}, CO, and BC could be crucial for improving birth outcomes, particularly in regions where solid fuels are commonly used for cooking.³³

A cohort study was conducted in Ghana to assess the impact of prenatal exposure to household air pollutants on birth outcomes, specifically size and gestational age at birth. The study, carried out from 2019 to 2021, included 1,200 pregnant women from rural and urban regions in Ghana. The primary objective was to determine the relationship between exposure to common indoor air pollutants, such as fine particulate matter (PM_{2.5}), carbon monoxide (CO), and other household pollutants, and infant birth outcomes. The results of the study revealed that higher levels of prenatal exposure to these pollutants were associated with smaller birth sizes and earlier gestational age at birth. In particular, each 10 µg/m³ increase in PM_{2.5} exposure during pregnancy was linked to a reduction in birthweight by approximately 45 grams (95% CI: 30, 60 gm) and the maternal exposure to CO was associated with a 0.7-week decrease in gestational age (95% CI: 0.3, 1.1 weeks), indicating an increased risk of preterm birth, and after controlling for potential confounders, including

maternal age, nutrition, and socioeconomic status, it was found that the associations between air pollution and reduced birth size and gestational age remained significant even after these adjustments. The study concludes the significant negative impact of household air pollution on fetal growth and development, particularly in areas with high exposure to indoor air pollutants and the need for interventions to reduce household air pollution in order to improve maternal and child health outcomes in Ghana and similar low-resource settings.³⁴

A cross-sectional study was conducted among 305 pregnant women in Australia who were non-smokers, to evaluate whether indoor air pollutants are associated with bad birth outcomes. Results of the study showed that formaldehyde was associated with low birth weight, preterm births and smaller for gestational age with a reduction in 0.044 of z-score birth weight ($p = 0.033$) and 0.05 reduction in head circumference z-score ($p = 0.06$) with every unit increase in formaldehyde. The study concluded that although there were very low formaldehyde concentrations, it was associated with reduced birth weight along with other adverse birth outcomes and this finding had shown consistency with other prior studies which suggest formaldehyde influences foetal development.³⁵

A prospective cohort study was carried out among 2,085 mother-infants between 2015 and 2018 to explore the association between ambient air pollution (NO_x , NO_2) and indoor air pollution (cooking fuel type) and fetal and neonatal death in Ethiopia. Results indicated that 69 fetal death instances, out of which 16 were miscarriages and 53 still-births along with 16 cases of neonatal deaths were identified. The findings also indicated a potential link between exposure to ambient NO_x (Nitric oxide) and NO_2 (Nitrogen dioxide) during pregnancy and an elevated risk of fetal death, as well as stillbirth but however, due to

the lack of statistical significance concluded from the analysis of the study, the results regarding indoor air pollution and neonatal death remain inconclusive.³⁶

A case-control study among women from rural maternity hospital in Ramanagara, Karnataka in 2017 to estimate the risk of low birthweight with prenatal exposure to indoor air pollution and the results indicated that the absence of exhaust ventilation the kitchen [OR = 3.76, 95% CI: (1.09-13.03)], regular use of incense materials [OR = 4.94, 95% CI: (1.12-21.73)] and lack of cross ventilation in the house [OR = 4.65, 95% CI: (1.60-13.51)] were identified to be the main risk factors associated with low birth weight. The study concluded that exposure to indoor air pollution during prenatal period, caused a elevated risk of low birth weight and also, pregnant women should be educated about the unknown harming effects of burning incense materials inside home and inadequate or poor ventilation which lead to air pollution indoors, that can affect the birth weight of newborns.³⁷

An epidemiological case - control study was conducted utilizing data from Demographic and Health Surveys from India, and two neighbouring countries between 1998 and 2016, to assess the risk for pregnancy loss attributable to PM_{2.5} exposure by using satellite-based PM_{2.5} measurements to assess ambient exposure during the period of pregnancy. Results revealed that the estimated mean concentration ranges of PM_{2.5} exposure for cases was 56 µg/mm³ and the mean level of PM_{2.5} exposure for controls was 54.57 µg/mm³ and for every 10 µg/mm³, there was an increase in the chance of pregnancy loss by 1.03 times [95% CI: (1.02, 1.05)] and an estimated 3,49,681 annual pregnancy losses were attributable to ambient air exposure higher than 40 µg/mm³, accounting to 7.1% [95% CI: (3.3, 31.2)] of the total annual burden of pregnancy losses in south Asia during that particular study period. The study concluded that the epidemiological estimates add to

evidence in literature, with regards to the association between loss of pregnancy outcomes and PM_{2.5} and suboptimal air quality contributing to a majority of the total proportion of pregnancy loss, so controlling PM_{2.5} pollution would promote maternal health.³⁸

A study was conducted among 7,75,768 live-births in Massachusetts to investigate the association between PM_{2.5} and birthweight at different points along the birthweight distribution. This study utilized quantile regression and estimated PM_{2.5} exposure based on geographically coded residential addresses of the research participants with high spatiotemporal resolution. The results showed a negative association between PM_{2.5} exposure and newborn birth weight and, an increase in interquartile range of PM_{2.5} was linked to an average reduction in birth weight of 16 gm (95% CI: 13, 19), a decrease of 19 gm for the lowest decile (95% CI: 15, 23) of birth weight, and a decrease of 14 gm for the highest decile (95% CI: 9, 19), whereas in general, the negative associations were more pronounced at lower deciles of birth weight and no evidence in modification of effect by socio-economic status of the individual or socio-economic standard of the neighbourhood was observed. The study concluded that PM_{2.5} exposure is negatively associated with birth weight, with stronger associations observed in full-term live births at lower quantiles of newborn birth weight.³⁹

A prospective cohort study was conducted in 2018 among 10.324 mother-live born infants in China to know the associations of environmental factors of the household like primary cooking fuel, housing renovation (HR), home ventilation (HV) with intrauterine growth restriction, preterm birth, low birth weight and term- low birth weight. Results showed that 5.4% of the total infants were preterm birth, 10.7% constituted to intrauterine growth restriction, 5.5% were low birth weight and 3% were term- low birth weight. Also, the households that used induction cookers as primary fuel during the pregnancy period

were associated with intrauterine growth restriction births [RR: 1.31, (95% CI: 1.07, 1.600)], low birth weight [RR: 1.62, (95% CI: 1.09, 1.82)] and term- low birth weight [RR: 1.62, (95% CI: 1.16, 2.26)], when compared to households that used gas a primary cooking fuel. And any household that underwent renovation within the duration of one year of pregnancy was associated with preterm birth [RR: 1.45, (95% CI: 1.06, 1.98)] and low birth weight [RR: 1.56, (95% CI: 1.17, 2.09)] as compared to households undergoing renovation during pregnancy that were associated with a elevated risk of intrauterine growth restriction in households with moderate ventilation [RR: 3.74, (95% CI: 1.69, 8.28)] only. The study concluded that proper ventilation might decrease the probable effects of housing renovations on pregnancy leading to small for gestational age.⁴⁰

A cohort study was conducted with 656 mothers and their infants, selected from the Durban birth cohort, which represents the birth cohort of inclusive maternal health and health of children under 5 years of age in relation to the environment, between 2013 and 2017 in South Africa, to investigate and explore maternal exposure to indoor and ambient air pollution during any time period of the pregnancy and the impact on adverse fetal outcomes, as and while controlling for various prenatal risk factors. The results determined that exposure to particulate matter, importantly PM_{2.5}, had both direct and indirect significant effects on the inadvertent risk towards several adverse fetal outcomes, including low birth weight and preterm birth. Furthermore, increased maternal exposure to sulphur dioxide (SO₂) was observed to be associated with a higher probability of experiencing newborn with intrauterine growth restriction and experiencing to be born prematurely. SO₂ exposure was found to mediate the relationship between PM_{2.5} and adverse outcomes, such as decreased birth weight than normal acceptable range and intrauterine growth restriction. Specifically, the study highlighted that maternal exposure to both PM_{2.5} and SO₂ during

pregnancy, after adjusting for various prenatal risk factors, was independently linked to an increased risk towards adverse fetal outcomes, including low birth weight, preterm birth, and intrauterine growth restriction. These findings underscore the causative pathologies on fetal development and birth outcomes due to air pollution.⁴¹

An epidemiological case - control study among 34,197 mothers between 1998 and 2016 in India, including Pakistan, along with Bangladesh to estimate the attributable pregnancy losses to PM_{2.5} exposures. The results indicated that the mean concentration level of PM_{2.5} exposure was 56.00 µg/m³ (SD: 30.82) for cases and 54.57 µg/ m³ (SD: 31.73) for controls and after adjusting for maternal age, non-linear terms for variation in different seasons, temperature and humidity, and long-term period of trends, every 10 µg/m³ increment of PM_{2.5} was associated with an odds ratio of 1.03 (95% CI: 1.02, 1.05) for pregnancy loss. Additionally, based on the estimated non-linear exposure-response function by age and residences of rural versus urban populations, it was estimated that 349,681 (95% CI: 152,932 - 489,493) pregnancy losses per year from 2000 to 2016 were attributed to ambient PM_{2.5} levels exceeding 40 µg/m³ (the annual PM_{2.5} standard in India), representing 7.1% (95% CI: 3.3, 31.2) of the total annual pregnancy loss burden in South Asia during this period. The study concluded that, in South Asia, a significant portion of the burden of pregnancy loss could be attributed to exposure to ambient concentrations of PM_{2.5}, and that air quality improvement would benefit by promoting global maternal and infant health.⁴²

A cohort study that was conducted between 2010 to 2015, among 1,285 pregnant women from both urban and rural households in Tamil Nadu to determine whether exposures to PM_{2.5} during pregnancy was associated with changes in birth weight, through estimations of PM_{2.5} during the period of pregnancy, using direct serial measurements of 24-

hour PM_{2.5} concentrations, that were performed at every trimester, showed results that indicated, 10 µg/m³ increase in PM_{2.5} exposure was found to be associated with a 4 g (95% CI: 1.08, 6.76). And after adjusting for maternal age, period of gestation, sex of infant, maternal BMI, birth order, season of conception, and history of a previous low birth weight child, there was increase in prevalence of low birth weight by 2% [OR = 1.02; 95% CI: 1.005, 1.041]. The study concludes the need for consideration of maternal PM_{2.5} exposures along with other risk factors that can cause low birth weight in India as they can lead to dual health problems from both household air pollution and ambient air pollution.⁴³

Methodology:

Source of Data: Pregnant women residing in Vantamuri and Bhutramanahatti, two subcenters of primary health center (PHC), Vantamuri, under the field practice area of Department of Community Medicine, Jawaharlal Nehru Medical College (JNMC), Belagavi, Karnataka, India.

Study Design: Longitudinal study

Study Period: 1st April 2023 to 31st March 2024

Study Area: Vantamuri, a rural region of Belagavi

Sample Size: 264 pregnant women residing in the study area.

Sample size was calculated using the prevalence of low birth weight among pregnant women exposed to indoor air pollution as 18.4%, based on the findings of a study conducted in South India.¹⁹

$$n = \frac{4 p q}{d^2}$$

‘p’ = prevalence

‘q’ = 100 – prevalence

$$n = \frac{4 \times 18.4 \times 81.6}{5 \times 5}$$

‘d’ = absolute error

$$= 240$$

240 + 10% loss to follow up

$$240 + 24 = 264$$

Vantamuri primary health center has 5 subcenters. Pregnant women residing in two subcenters, Vantamuri and Bhutaramanahatti were randomly selected as study participants.

Birth rate of Vantamuri PHC is 17 per 1000 population.

Subcentres	Total population	Number of pregnant women	Proportionate to size
Vantamuri	9441	$17 \times 9441 \div 1000 = 160$ $160 + 10\% \text{ pregnancy wastage}$ $= 160 + 16 = 176$	157
Bhutramatti	6387	$(17 \times 6387) \div 1000 = 108$ $108 + 10\% \text{ pregnancy wastage}$ $= 108 + 11 = 119$	106
Total	15,828	$176 + 119 = 295$	264

So, 264 pregnant women were chosen from the two subcentres, proportionate to size, using Simple random sampling.

Method of data collection: Pregnant women residing in Vantamuri and Bhutramanhatti, registered under Vantamuri PHC, Belagavi, from 1st April 2023 to 31st March 2024 were enrolled as study participants.

After taking informed consent from the study participants, information regarding sociodemographic variables, maternal health characteristics, general household characteristics, kitchen characteristics, environmental factors like presence of cattle shed or livestock or domestic animals in the household premises, type of fuel used for cooking, various sources of indoor air pollution, previous history of adverse birth outcomes such as low birth weight, abortion, pre-term, intra-uterine death along with birth weight of the present pregnancy, were collected using pre-tested and predesigned questionnaire.

Anthropometric measurements such as height and weight were measured. Body Mass Index (BMI) of the individual participant was calculated. Haemoglobin was also taken into consideration.

PM_{2.5} concentrations for 24-hours were estimated in the kitchens of participants' households using Atmos air quality monitor, Model 1 with PM Sensor, by Respirer Living Sciences, Mumbai.

The device was placed in the kitchen area for a continuous time period of 24 hours, after which it was shifted to the household of the next pregnant woman, who is in the same locality or nearby area. The data from the device automatically recorded, saved and uploaded to the memory storage card of the device after completion of every 24-hour measurement. From the acquired 24-hour measurements of PM_{2.5} concentrations from individual households, the average 24-hour PM_{2.5} concentration was then derived using Python coding for the household of every participant respectively.

Inclusion criteria: Pregnant women residing in the study area for more than one year

Exclusion criteria: Pregnant women with any medical conditions at the time of enrolment.

Pregnant women not willing to give consent.

Ethical clearance: The study received approval from the Institutional Ethics committee for Human Subjects Research, KAHER, Jawaharlal Nehru Medical College, Belagavi.

Ref. No. MDC/JNMCIEC/51 dated 07/04/2023.

Informed consent: Written informed consent was obtained from each participant prior to enrollment in the study.

Statistical analysis: Data was analysed using statistical software **R** software version 4.1.2 and Microsoft Excel. Categorical variables are given in the form of frequency table. Continuous variables are given in Mean \pm SD. To compare continuous variables with normality over a group t-test/ANOVA was used and for variables without normality Mann-Whitney test / Kruskal-Wallis test was used. To check the association between categorical variables Chi-square test was used. Multiple Linear regression and logistic regression was used to find the potential association between PM_{2.5} levels and the adverse birth outcomes. P-value less than equal to 0.05 was considered as statistically significant.

Definition of study variables:

1. **Age:** Calendar age in years was considered for the study (nearest completed years).

2. **Address:** Residential address was taken into consideration.

3. **Occupation:**

Employed⁵¹: “An occupation by which a person earns a living.”

Unemployed⁵²: “Not engaged in a gainful occupation.”

4. **Education status**⁵³:

Illiterate: “A person who could not read and write any language.”

Primary school: “A person who had studied from first to seventh standard.”

High school: “A person had studied 8th standard to 12th standard.”

PUC or diploma: “Person who has studied up to PUC 2nd year or a Diploma Course.”

Graduation: “A person who had a bachelor’s degree in any field.”

5. **Marital status:** Marital status was classified as: married, unmarried, widow, divorcee.

6. **Religion**⁵⁴: “An organized system of beliefs, ceremonies, and rules used to worship a God or groups or Gods. For examples Hindu, Muslims and Christian.”

7. **Family**⁵⁷:

Nuclear family: “Married couple along with their dependent children who live in the same house”.

Joint family: “More than one married couple along with their dependent children who live in the same household. Male members are blood relatives and female members of the family are related by either marriage or blood.”

8. Socio economic status⁵⁵:

Modified B. G. Prasad's classification was used

Social Class		Original BG Prasad classification of 1961 (Rs. /- month)	Modified BG Prasad classification for 2024 (Rs. /- month)
I	Upper class	Above 100	9,196 and above
II	Upper middle class	50 - 99	4,598 - 9,195
III	Middle class	30 - 49	2,758 - 4,597
IV	Lower middle class	15 - 29	1,379 - 2,757
V	Lower class	Below 15	Below 1,378

The BG Prasad Scale, established in 1961 with the Consumer Price Index (CPI) of 1960 as the reference point (indexed at 100), has undergone periodic updates. Over the years, adjustments and refinements have been necessary. To recalibrate the CPI to the 1960 baseline of 100, linkage factors were introduced in the years 1982, 2001, and 2016, with values of 4.63, 4.93, and 2.88, respectively.

Average consumer price index from March 2023 to April 2024 - 139.89

Correction factor = current index value (139.89) × linkage factor between 1960 and 1982 (4.63) × linkage factor between 1982 and 2001 (4.93) × linkage factor between 2001 and 2016 (2.88) whole divided by base index in 2016 (100) = 91.96

9. Type of house⁵⁶:

Kucha: “The walls and/or roof of which are made of material other than those mentioned above, such as unburnt bricks, bamboos, mud, grass, reeds, thatch, loosely packed stones, etc. are treated as kutch house.”

Semi pucca: “A house that has fixed walls made up of pucca material but roof is made up of the material other than those used for pucca house.”

Pucca: “A pucca house is one, which has walls and roof made of the following material. Wall material: Burnt bricks, stones (packed with lime or cement), cement concrete, timber, ekra etc.”

10. Overcrowding⁵⁷: “Is expressed as the number of persons divided by the number of rooms. It is called overcrowding if these standards are exceeded.”

“Criteria for overcrowding – persons per room”

“1 room - 2 persons”

“2 rooms - 3 persons”

“3 rooms - 5 persons”

“4 rooms - 7 persons”

“5 or more rooms - 10 persons”

11. Ventilated⁵⁸: Natural ventilation was taken into consideration

Natural ventilation: “Natural forces (e.g. winds and thermal buoyancy force due to indoor and outdoor air density differences) drive outdoor air through purpose- built, building envelope openings. Purpose-built openings include windows, doors, solar chimneys, wind towers and trickle ventilators.”

12. Dampness⁶¹: “any visible, measurable or perceived outcome of excess moisture that causes problems in households, such as mould, leaks or material degradation, mold odor or directly measured excess moisture (in terms of relative humidity or moisture content or microbial growth) are called dampness.”

13. Tobacco use⁶²: “For the assessment of history of use of tobacco in any form (smoking/smokeless) period of recall was considered for the past one year.”

Smoking tobacco:

Smokers: “Subjects those who had smoked in the past or smoking at present were considered as smokers.”

Non-Smokers: “Subjects who had never smoked any form of tobacco (Cigarettes/Beedi) were considered as non-smokers.”

14. Alcohol consumption⁶³: “For the assessment of alcohol consumption, period of recall was considered for the past one year.”

Alcoholic: “A person who has been taking alcohol at least 30 ml per day for at least six months preceding the survey.”

Non-Alcoholic: “Subject who had never consumed alcohol were considered and kept in the category of Non-Alcoholic.”

15. Body Mass Index (BMI)⁵⁷: According to the guidelines recommended by WHO, persons with BMI values of less than 18.5 were classified as “Underweight”, 18.5 to 24.9 were classified as “Normal weight”, 25 to 29.99 were classified as “over-weight” and 30 and above were classified as “Obese”.

Body Mass Index was calculated as; $BMI = \text{weight in kgs} / (\text{Height in Meter})^2$

Classification of BMI:

Normal range: 18.50 - 24.99

Under weight: ≤ 18.5

Overweight: $\geq 25.00 - 29.99$

Obese: ≥ 30

16. Anaemia:

Haemoglobin concentration below a specified cut-off point; that cut-off point depends on the age, gender, physiological status, smoking habits and altitude at which the population being assessed lives.⁵⁹

According to WHO, during pregnancy, Anaemia is identified by haemoglobin levels less than 11.0 g/dL⁶⁰

Classification of Anaemia⁶⁰:

Mild anemia (Hb levels): 9 to 10.9 g/dL

Moderate anemia (Hb levels): 7 to 8.9 g/dL

Severe anemia (Hb levels) less than 7 g/dL

17. PM_{2.5}¹¹: Particulate matter (2.5) is an air pollutant, PM_{2.5}, defined as, “fine particulate matter with diameter of 2.5 µm or less”

18. Indoor air pollution¹²: According to World health organisation air quality guidelines, for Indian standard levels of PM_{2.5}, more than 40 µg/m³ will be considered as indoor air pollution.

19. Term baby⁶⁴: A healthy baby born at term which is between 38 weeks and 42 weeks of gestation, should have an average birth weight for the country (usually exceeds 2,500 gm), cries immediately after birth, establishes independent rhythmic respiration and quickly adapts to the changed environment.

20. Preterm baby⁶⁴: A baby born before 37 completed weeks of gestation regardless of birth weight calculating from the day of last menstrual period.

21. Low Birth Weight (LBW) baby⁶⁴: Baby born with birth weight less than 2,500 gm irrespective of the gestational age.

- 22. Stillbirth⁶⁴:** A stillbirth is the birth of a new-born after 28th completed week (weighing 1000 gm or more) when the baby does not breathe or show any sign of life after delivery.
- 23. Abortion⁶⁴:** It is the expulsion or extraction from its mother of an embryo or foetus weighing 500 gm or less when it is not capable of independent survival.
- 24. Normal Vaginal Delivery⁶⁴:** A normal vaginal delivery is a vaginal birth that happens without complications for the mother or fetus. It can be spontaneous or induced, and can be assisted with instruments like forceps or a vacuum.
- 25. Lower Section Caesarean Delivery⁶⁴:** It is a surgical procedure that involves delivering a baby through an abdominal incision (laparotomy) and a uterine incision (hysterotomy).

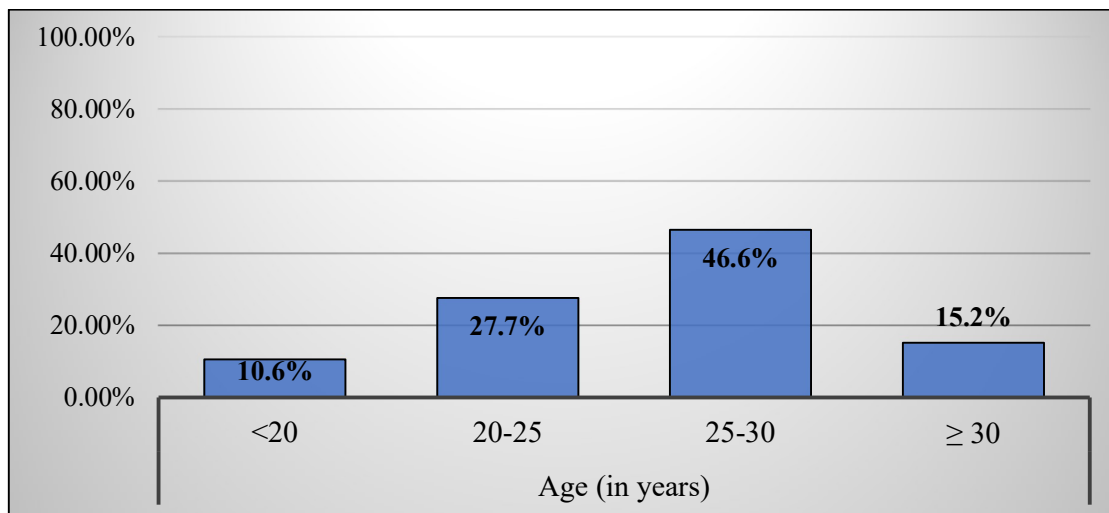
Results:

I. Socio-demographic characteristics

Table 1: Distribution of study participants according to age

Age in years	Number	Percentage (%)
< 20	28	10.61
20-25	73	27.65
25-30	123	46.59
≥ 30	40	15.15
Total	264	100

Graph 1 (Table 1): Distribution of age among study participants

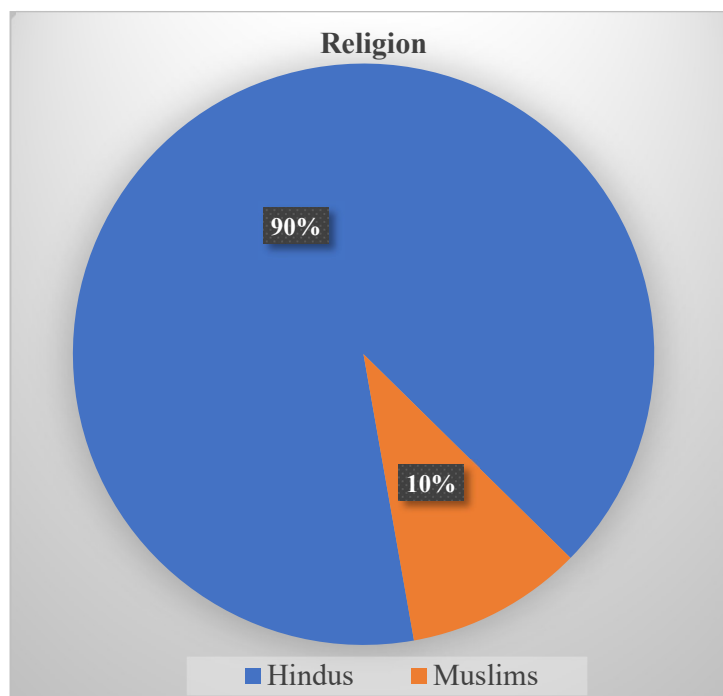


In the present study, the mean age of the study participants is 24.45 ± 4.29 years out of 264 participants, 28 (10.61%) were aged less than 20 years, 73 (27.65%) were aged in between 20-25 years, 123 (46.59%) were aged in between 25-30 years and 40 were aged 30 years or more.

Table 2: Distribution of study participants according to religion

Religion	Number	Percentage (%)
Hindu	238	90.15
Muslim	26	9.85
Total	264	100

Graph 2 (Table 2): Distribution of study participants according to religion

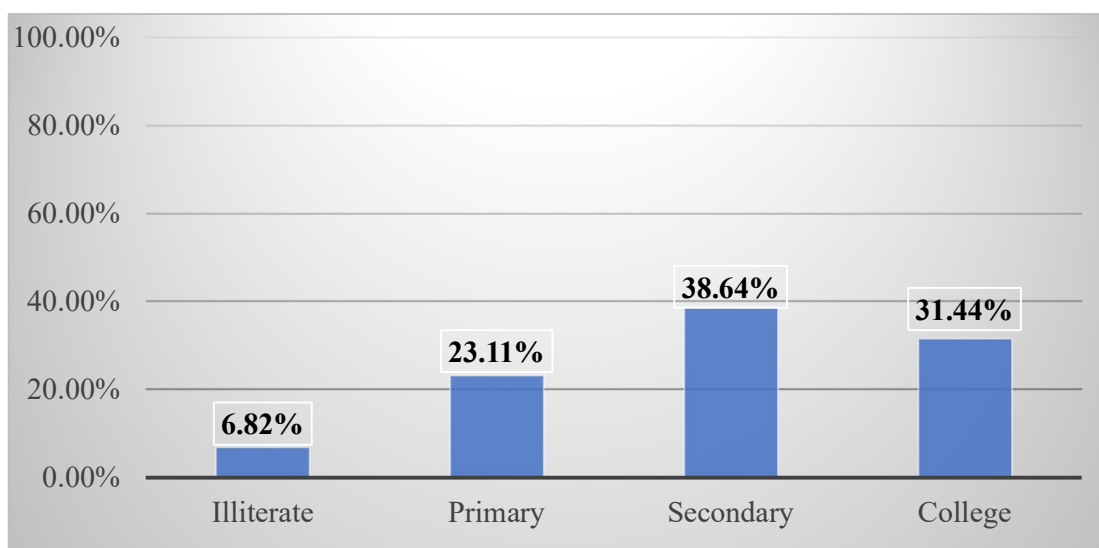


In the present study, out of 264 participants, 238 (90.15%) were Hindus and 26 (9.85%) were Muslims.

Table 3: Distribution of study participants according to literacy status

Education	Number	Percentage (%)
Illiterate	18	6.82
Primary	61	23.11
Secondary	102	38.64
College	83	31.44
Total	264	100

Graph 3 (Table 3): Distribution of study participants according to literacy status

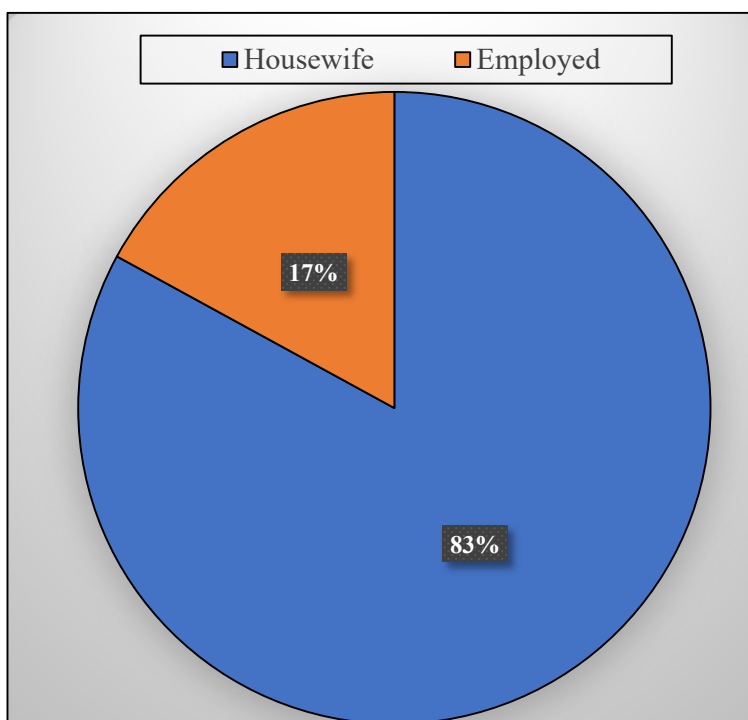


In the present study, out of 264 participants, 18 (6.82%) were illiterates, 61 (23.11%) attained Primary education, 102 (38.64%) attained Secondary education and 83 (31.44%) were Collegiate.

Table 4: Distribution of study participants according to occupation

Occupation	Number	Percentage (%)
Housewife	219	82.95
Employed	45	17.05
Total	264	100

Graph 4 (Table 4): Distribution of participants according to occupation



In the present study, out of 264 participants, 219 (82.95%) were housewives and 45 (17.05%) were employed.

Table 5: Distribution of study participants according to literacy status of husband

Education of husband	Number	Percentage (%)
Illiterate	24	9.09
Primary	38	14.39
Secondary	88	33.33
College	114	43.18
Total	264	100

In the present study, out of 264 participants, 24 (9.09%) of the participants' husbands were uneducated, 38 (14.39%) attained primary education, 88 (33.33%) attained secondary education, 114 (43.18%) were collegiate.

Table 6: Distribution of study participants according to occupation of husband

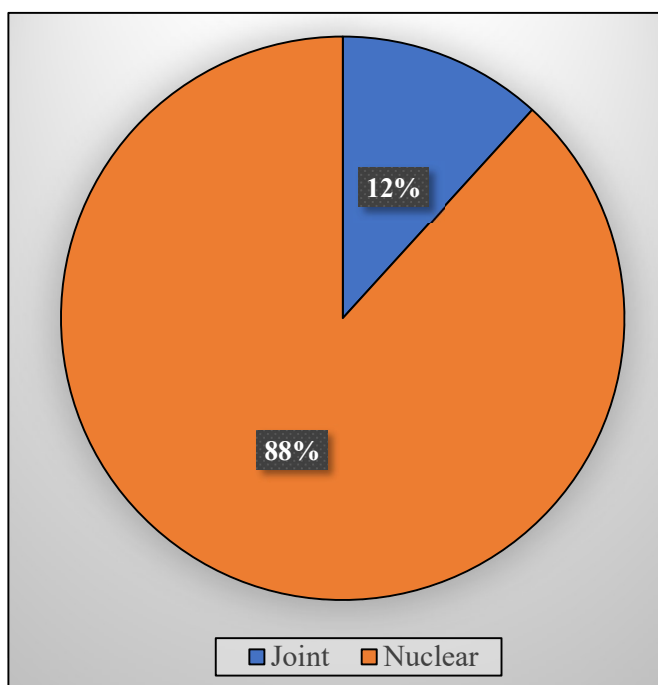
Occupation of Husband	Number	Percentage (%)
Unemployed	3	1.14
Employed	261	98.86
Total	264	100

In the present study, out of 264 participants, 261 (98.865) of the participants' husbands were employed and three (1.14%) were unemployed.

Table 7: Distribution of study participants according to type of family

Type of Family	Number	Percentage (%)
Joint	31	11.74
Nuclear	233	88.26
Total	264	100

Graph 5 (Table 7): Distribution of participants according to type of Family

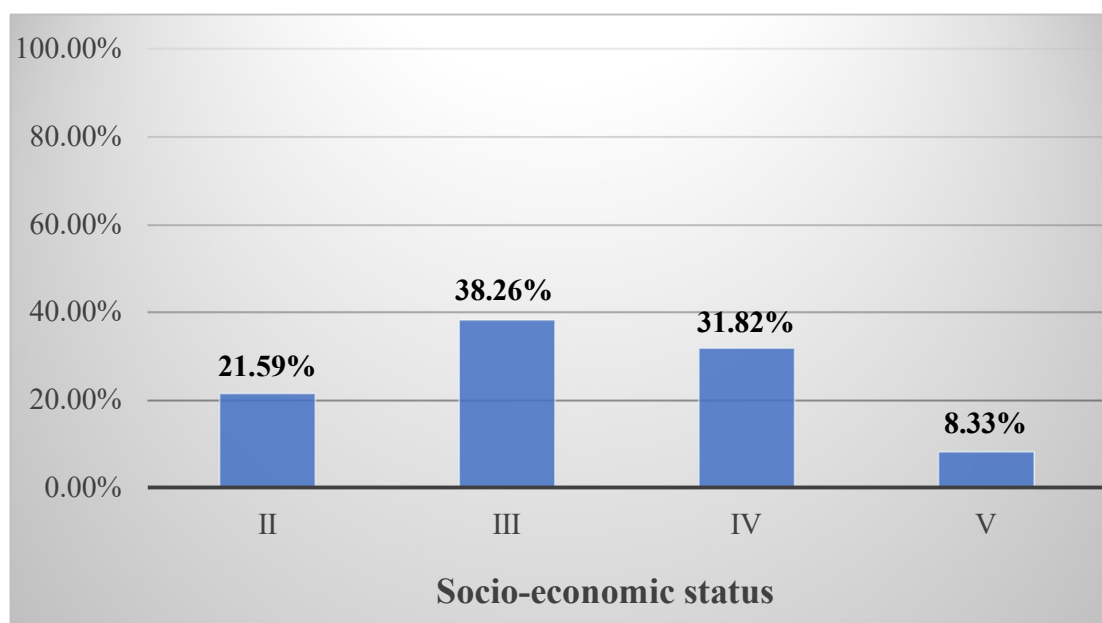


In the present study, out of 264 participants, 233 (88.26%) were living in nuclear family and 31 (11.74%) were living in joint family.

Table 8: Distribution of study participants according to socio-economic status

Socio-economic status	Number	Percentage (%)
II	57	21.59
III	101	38.26
IV	84	31.82
V	22	8.33
Total	264	100

Graph 6 (Table 8): Distribution of participants according to socio-economic status

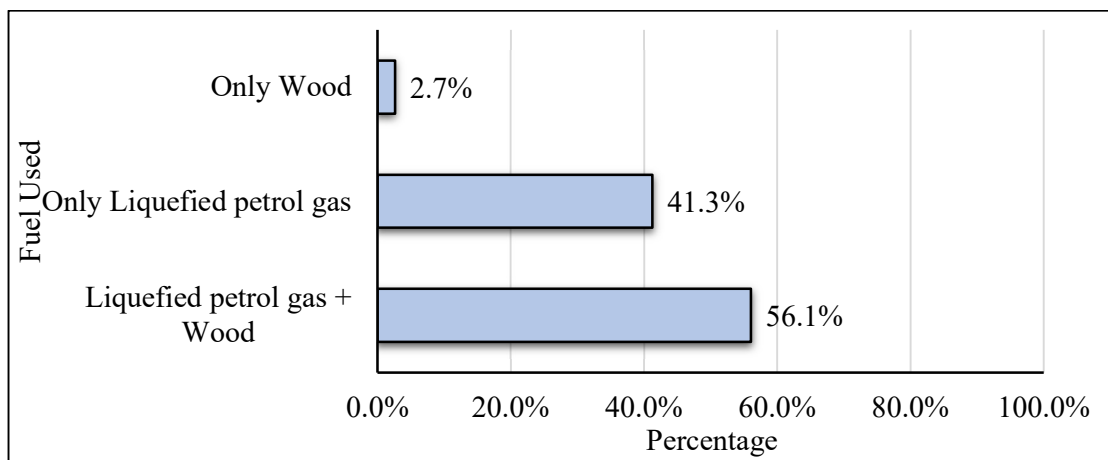


In the present study, according to Modified BG Prasad socio-economic classification, out of 264 participants, 57 (21.59%) belonged to class II, 101 (38.26%) belonged to class III, 84 (31.82%) belonged to class IV and 22 (8.33%) belonged to class V.

Table 9: Distribution of study participants according to sources of indoor air pollution

Sources of Indoor air pollution		Number	Percentage (%)
Passive smoking		113	42.8
Usage of Incense sticks		210	79.55
Usage of Mosquito coils		95	35.98
Fuel used for cooking	Liquified Petroleum Gas + Wood	148	56.06
	Only Liquefied Petroleum Gas	109	41.29
	Only Wood	7	2.65

Graph 7 (Table 9): Distribution of study participants according to their preference of cooking fuel



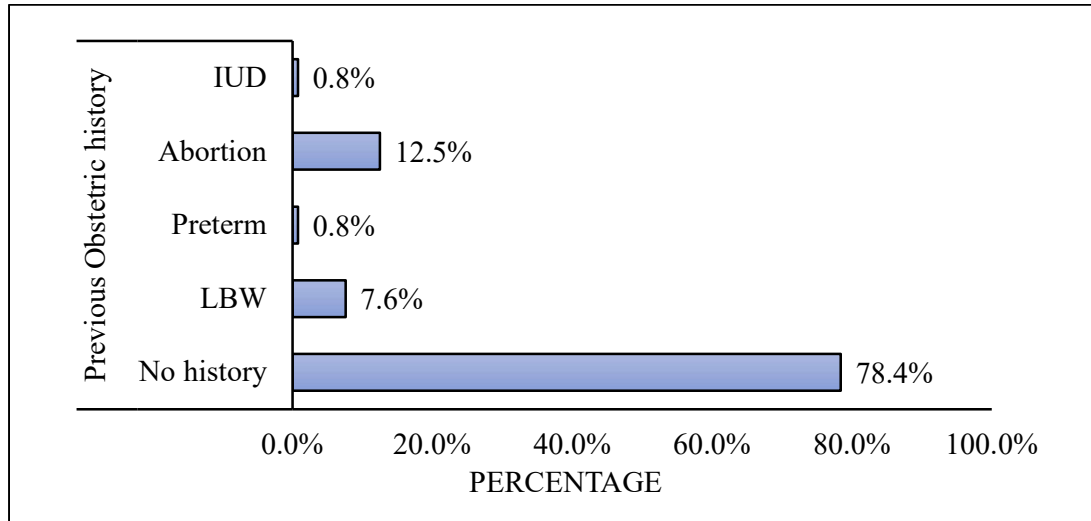
In the present study, out of 264 participants, 113 (42.8%) were passive smokers, 210 (79.55%) of the participants had the habit of usage of incense sticks and 95 (35.98%) had the habit of usage of mosquito coils. The choice of fuel for cooking for 148 (56.06%) participants was both liquid petroleum gas and wood, for 109 (41.29%) it was only liquid petroleum gas and for seven (2.65%) the choice of cooking fuel was only wood.

II. Maternal characteristics of study participants

Table 10: Distribution of study participants according to previous obstetric history

Previous Obstetric history	Number	Percentage (%)
No bad Obstetric history	207	78.41
History of Low birth weight	20	7.58
History of Preterm	2	0.76
History of Abortion	33	12.5
History of Intra-Uterine Death	2	0.76
Total	264	100%

Graph 8 (Table 10): Distribution of participants as per their previous obstetric history



In the present study, out of 264 participants, 207 (78.41%) had no history of bad obstetric outcomes, 20 (7.58%) had history of low birth weight, two (0.76%) had history of preterm and 33 (12.5%) had history of abortion and two (0.76%) had history of Intra-uterine Death.

Table 11: Distribution of study participants according to number of Live births

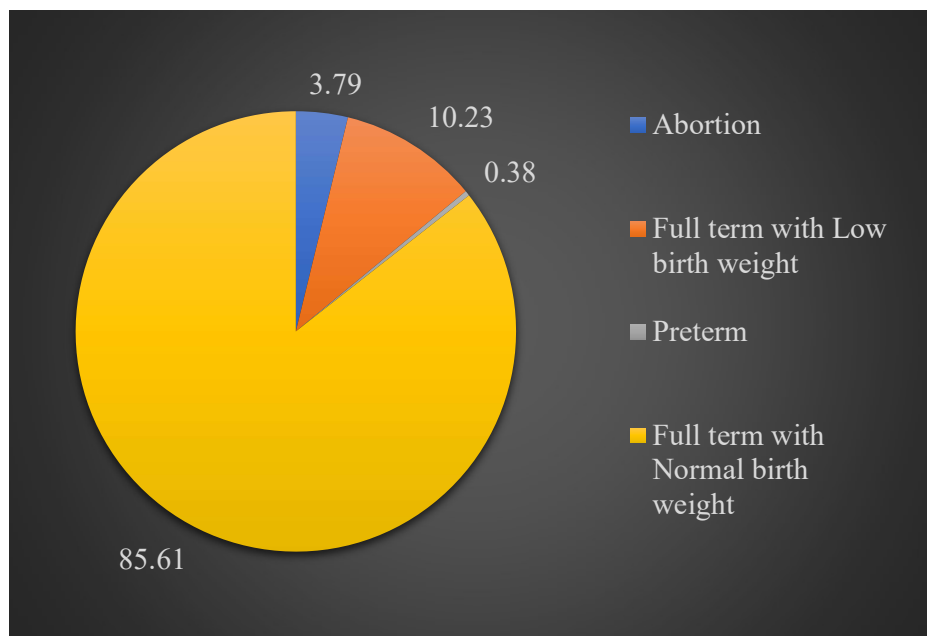
Number of Live births	Number	Percentage (%)
0	136	51.52
1	100	37.88
2	17	6.44
3	10	3.79
4	1	0.38
Total	100	100

In the present study, out of 264 participants, 136 (51.52%) were Primigravida, 100 (37.88%) had 1 live birth from previous pregnancy, 17 (6.44%) had 2 live births, 10 (3.79%) had three live births and one (0.38%) had four live births from previous pregnancies.

Table 12: Distribution of study participants according to outcomes of pregnancy

Outcome	Number of subjects	Percentage (%)
Abortion	10	3.79
Full term with Low birth weight	27	10.23
Preterm	01	0.38
Full term with Normal birth weight	226	85.61
Total	264	100

Graph 9 (Table 12): Distribution of study participants according to outcomes of pregnancy

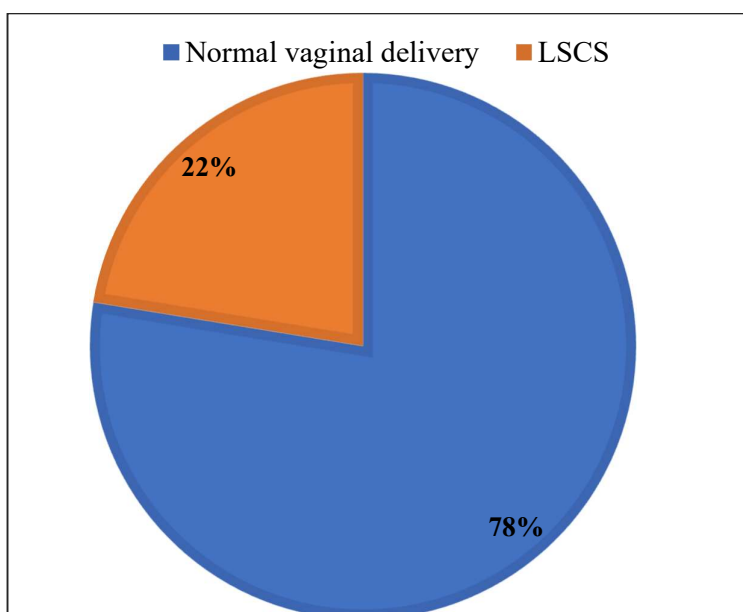


In the present study, out of 264 participants, 10 (3.79%) had history of abortion, 27 (10.23%) had history of full-term baby with Low birth weight, one (0.38%) had history of Preterm birth, and 226 (85.61%) had full term baby with normal birth weight.

Table 13: Distribution of study participants according to mode of delivery

Mode of Delivery	Number of subjects	Percentage (%)
Normal vaginal delivery	204	77.27
LSCS	59	22.35
Total	264	100

Graph 10 (Table 13): Distribution of study participants according to mode of delivery

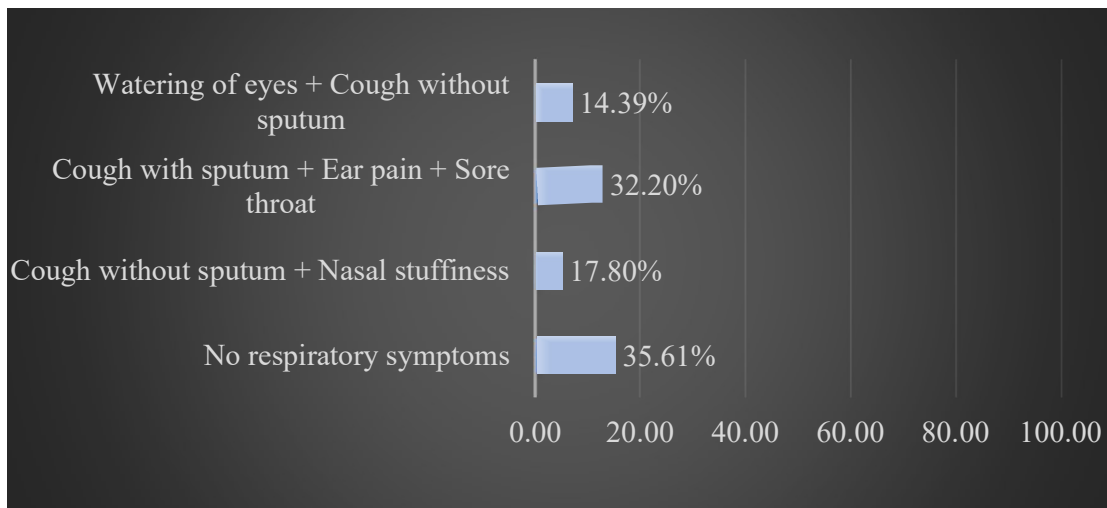


In the present study, out of 264 participants, 204 (77.27%) delivered through normal vaginal delivery and 59 (22.35%) underwent Lower Section Caesarean Section.

Table 14: Distribution of study participants according to respiratory symptoms

Respiratory symptoms	Number	Percentage (%)
No respiratory symptoms	94	35.61
Cough without sputum + Nasal stuffiness	47	17.8
Cough with sputum + Ear pain + Sore throat	85	32.2
Watering of eyes + Cough without sputum	38	14.39
Total	264	100

Graph 11 (Table 14): Distribution of study participants according to their health status



In the present study, out of 264 participants, 94 (35.61%) had no health complaints, 47 (17.8%) had Cough without sputum associated with nasal stuffiness, 85 (32.2%) had Cough with sputum associated with ear pain and sore throat, and 38 (14.39%) had Watering of eyes associated with cough without sputum.

Table 15: Distribution of study participants according to status of anaemia

Anaemia	Number of subjects	Percentage (%)
No Anaemia	119	45.08
Mild	120	45.45
Moderate	25	9.47
Total	264	100

In the present study, out of 264 participants, 119 (45.08%) were not anaemic, 120 (45.45%) had mild anaemia and 25 (9.47%) had moderate anaemia.

III. Anthropometric profile

Table 16: Distribution of study participants according to Body Mass Index (BMI)

Body Mass Index (kg/m²)	Number of subjects	Percentage (%)
Normal weight	46	17.42
Underweight	152	57.58
Overweight	59	22.35
Obese	7	2.65
Total	264	100

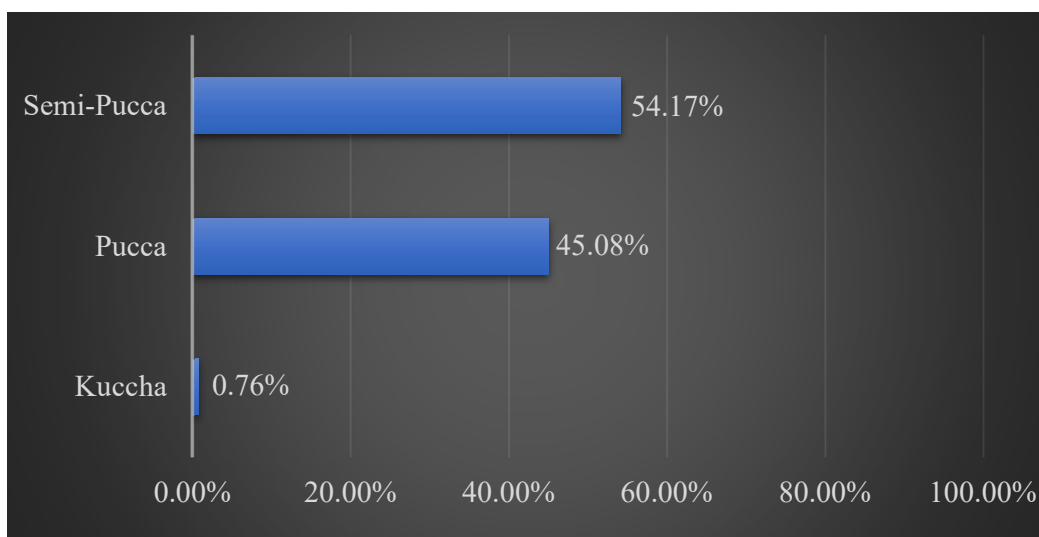
In the present study, the mean BMI of the study participants was 22.12 ± 3.92 , out of 264 study participants, 46 (17.42%) were underweight, 152 (57.58%) had normal weight, 59 (22.35%) were overweight, and seven (2.65%) were obese.

IV. Housing characteristics

Table 17: Distribution of study participants according to type of house

Type of house	Number	Percentage (%)
Kuccha	02	0.76
Pucca	119	45.08
Semi-Pucca	143	54.17
Total	264	100

Graph 12 (Table 17): Distribution of study participants according to type of house

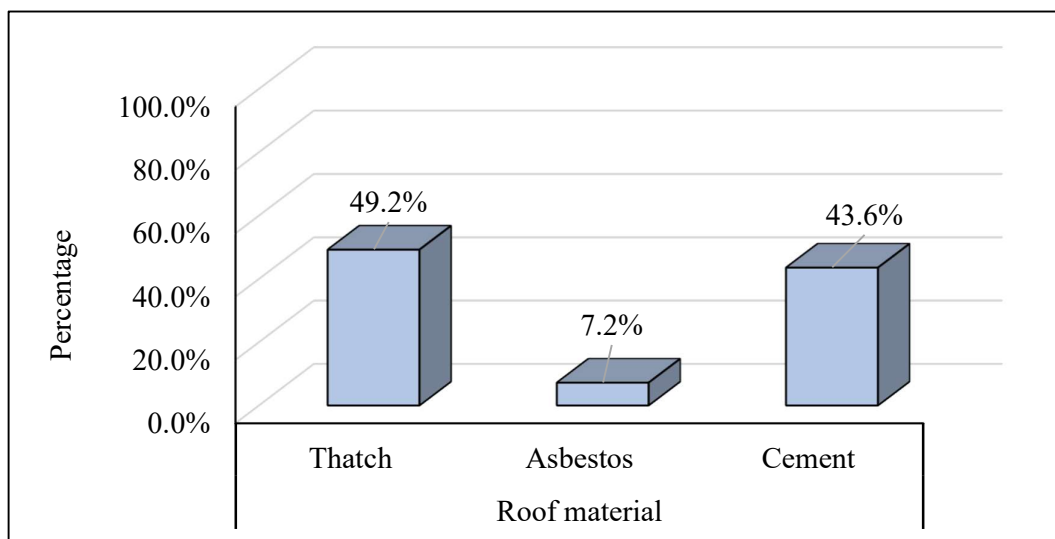


In the present study, out of 264 participants, two were living in kuccha houses, 143 were living in semi-pucca houses and 119 were living pucca houses.

Table 18: Distribution of study participants according to roof material of house

Roof material of house	Number	Percentage (%)
Thatched roof	130	49.24
Asbestos roof	19	7.20
Cemented roof	115	43.56
Total	264	100

Graph 13 (Table 18): Distribution of study participants according to roof material of the household



In the present study, out of 264 participants, 130 (49.24%) were living in house with thatch roof, 19 (7.2%) were living in houses with asbestos roof and 115 (43.56%) were living in houses with cement roof.

Table 19: Distribution of study participants according to dampness in the house

Dampness in the house	Number	Percentage (%)
Dampness present	163	61.74
Dampness absent	101	38.26
Total	264	100

In the present study, out of 264 participants, 163 had dampness in their households and 101 did not have dampness in the household.

Table 20: Distribution of study participants according to over-crowding

Over-crowding	Number	Percentage (%)
Present	207	78.41
Absent	57	21.59
Total	264	100

In the present study, out of 264 participants, 207 (78.41%) were living in houses with overcrowding and 57 (21.59%) were living in houses with no overcrowding.

Table 21: Distribution of study participants according to ventilation of the house

Ventilation of the house	Number	Percentage (%)
Adequate ventilation	52	19.7
Inadequate ventilation	212	80.3
Total	264	100

In the present study, out of 264 participants, 52 (19.7%) were living in well-ventilated houses and 212 (80.3%) were not living in well-ventilated houses.

Table 22: Distribution of study participants according to presence of domestic animals inside the house

Domestic animals inside the house	Number	Percentage (%)
Present	120	45.45
Absent	144	54.55
Total	264	100

In the present study, out of 264 participants, 120 (45.45%) had domestic animals in their household and 144 (54.55%) did not have domestic animals in their house.

Table 23: Distribution of study participants according to PM_{2.5}/mm³ concentrations in participants' households

Ranges of PM_{2.5}/mm³ in participants' households	Number of subjects	Percentage (%)
≤40 mm ³	55	20.83
41-79 mm ³	59	22.35
≥80 mm ³	150	56.82
Total	264	100

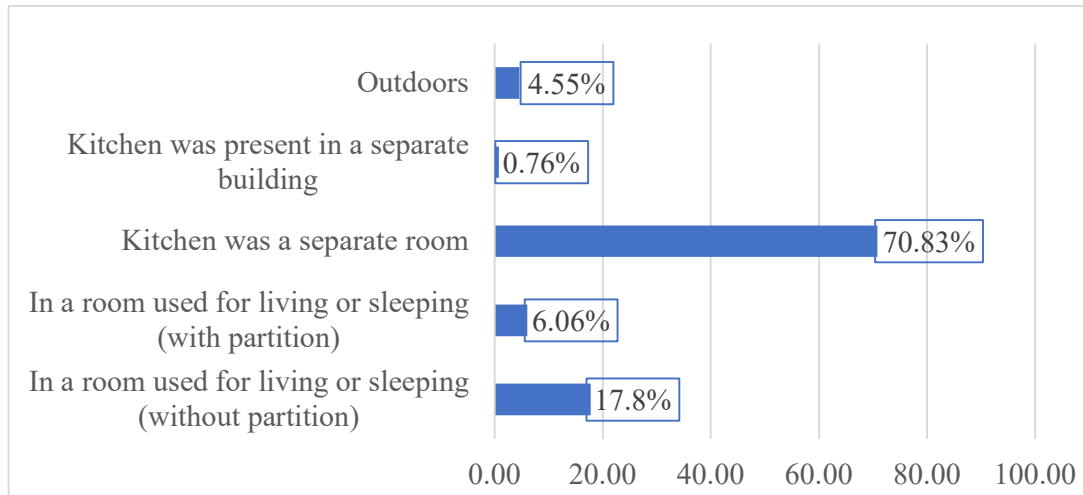
In the current study, as per 24-hour PM_{2.5} concentrations measured by the Air Quality monitor, among the households of 264 participants, the mean was 122.74 ± 88.09 , 55 (20.83%) had 40/mm³ or less PM_{2.5} concentration in their households, 59 (22.35%) had 41-79/mm³ PM_{2.5} concentration in their households and 150 (56.82%) had 80/mm³ or more PM_{2.5} concentration in their households.

V. Cooking characteristics

Table 24: Distribution of study participants according to area of cooking

Area of cooking	Number of subjects	Percentage (%)
In a room used for living or sleeping (without partition)	47	17.8
In a room used for living or sleeping (with partition)	16	6.06
Kitchen was a separate room	187	70.83
Kitchen was present in a separate building	2	0.76
Outdoors	12	4.55
Total	264	100

Graph 14 (Table 24): Distribution of study participants according to area of cooking



In the present study, for their area of cooking, out of 264 participants, 47 (17.8%) used a living or sleeping room without partition, 16 (6.06%) used a living or sleeping room with partition, 187 (70.83%) had a separate room used as kitchen, two (0.76%) used a separate building used as kitchen and 12 (4.55%) used outdoors as kitchen.

Table 25: Distribution of study participants according to cross-ventilation in kitchen

Cross-ventilation in kitchen	Number of subjects	Percentage (%)
Present	104	39.39
Absent	160	60.61
Total	264	100

In the present study, out of 264 participants, 104 (39.39%) had cross-ventilation in their kitchen and 160 (60.61%) did not have cross-ventilation in their kitchen.

Table 26: Distribution of study participants according to involvement in cooking at present

Involved in cooking at present	Number of subjects	Percentage (%)
Present	247	93.56
Absent	17	6.44
Total	264	100

In the present study, out of 264 participants, 247 (93.56%) were involved in cooking during the study period and 17 (6.44%) were not involved in cooking during the study period.

Table 27: Distribution of study participants according to reason for choice of fuel used

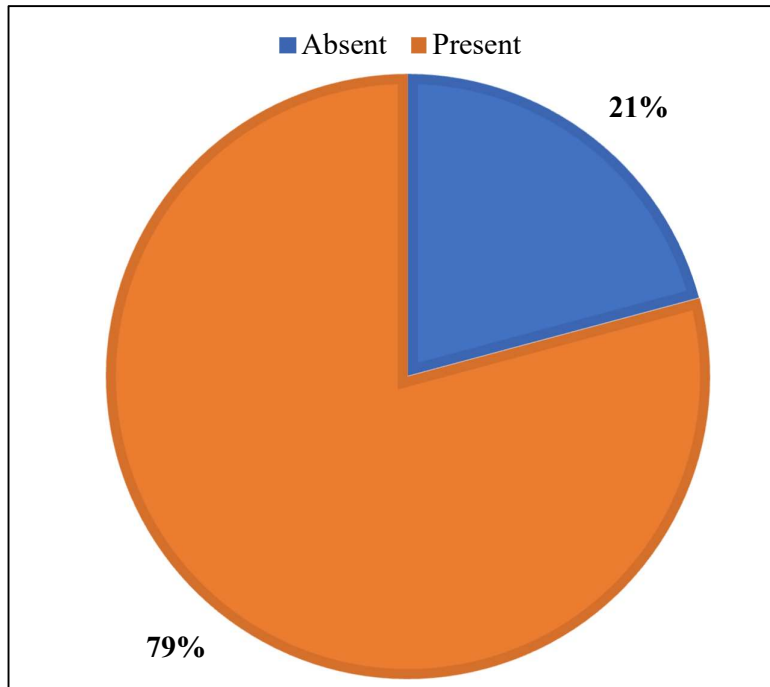
Reason for choice of fuel	Number of subjects	Percentage (%)
Habituated	65	24.62
Government supply	135	51.14
Easily affordable	4	1.52
Fuel is of better quality	1	0.38
Fuel produces less smoke	3	1.14
Takes lesser time to cook	56	21.21
Total	264	100

In the present study, among the 264 participants, the various reasons for using cooking fuel of their choice was, 64 were habituated to their choice of cooking fuel, 135 had government supply of the cooking fuel, four considered their cooking fuel was easily affordable, one considered the cooking fuel was of better quality, three preferred their cooking fuel because it produced less smoke and 56 preferred their cooking fuel because it took lesser time to cook.

Table 28: Distribution of study participants according to exposure to indoor air pollution and adverse birth outcomes

Indoor air pollution	Number	Percentage (%)
Present	209	79.1
Absent	55	20.8
Total	264	100
Adverse birth outcomes	Number	Percentage (%)
Present	38	14.3
Absent	226	85.6
Total	264	100

Graph 15 (Table 28): Distribution of study participants according to Indoor air pollution



In the current study, out of 264 participants, 209 (79.1%) had exposure to indoor air pollution and 38 (14.3%) participants had adverse birth outcome in their present pregnancy.

VI. Association between socio-demographic factors and adverse birth outcomes

Table 29: Association between age of the participant and adverse birth outcomes

Age in years	Adverse birth outcomes		Total	p-value
	Present	Absent		
< 20	7 (25%)	21 (75%)	28 (100%)	0.2458 ^{MC}
20-25	18 (14.63%)	105 (85.37%)	123 (100%)	
25-30	10 (13.7%)	63 (86.3%)	73 (100%)	
≥ 30	3 (7.5%)	37 (92.5%)	40 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 4.133$			df = 3	

Abbreviation: MC: Monte-Carlo's simulation used in Chi-square test

In the present study, seven (25%) out of 28 study participants with less than 20 years of age had adverse birth outcomes. 18 (14.63%) out of 123 in the age group of 20-25 years, 10 (13.7%) out of 73 in the age group of 25-30 years and three (7.5%) out of 40 participants of 30 years age and more, had adverse birth outcomes. It was found that participants less than 20 years of age had more adverse birth outcomes compared to other age groups. However, significant association was not found between age and adverse birth outcomes ($p = 0.2458$).

Table 30: Association between religion of the participant and adverse birth outcomes

Religion	Adverse birth outcomes		Total	p-value
	Present	Absent		
Hindu	35 (14.71%)	203 (85.29%)	238 (100%)	0.7790 ^{MC}
Muslim	3 (11.54%)	23 (88.46%)	26 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 0.1908$			df = 1	

Abbreviation: MC: Monte-Carlo's simulation used in Chi-square test

In the present study, out of 238 Hindu participants, 35 (14.71%) had adverse birth outcomes and out of 26 Muslim participants, three (11.54%) had adverse birth outcomes but there was no association between religion and adverse birth outcomes ($p = 0.7790$).

Table 31: Association between education of the participant and adverse birth outcomes

Education	Adverse birth outcomes		Total	p-value
	Present	Absent		
Illiterate	1 (5.56%)	17 (94.44%)	18 (100%)	0.1101 ^{MC}
Primary	14 (22.95%)	47 (77.05%)	61 (100%)	
Secondary	11 (10.78%)	91 (89.22%)	102 (100%)	
College	12 (14.46%)	71 (85.54%)	83 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 5.8447$			df = 3	

Abbreviation: MC: Monte-Carlo's simulation used in Chi-square test

In the present study, out of 17 illiterates, one had adverse birth outcome. Out of 61 participants with primary level education, 14 (22.95%) had adverse birth outcomes. 11 (10.78%) out of 102 participants, 12 (14.46%) out of 83 with secondary and college education respectively had adverse birth outcomes. There was no association between education of the study participant and adverse birth outcomes (p = 0.1101).

Table 32: Association between occupation of the participant and adverse birth outcomes

Occupation	Adverse birth outcomes		Total	p-value
	Present	Absent		
Employed	7 (15.22%)	39 (84.78%)	46 (100%)	0.861
House wife	31 (14.22%)	187 (85.78%)	218 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 0.0307$			df = 1	

In the current study, seven (15.22%) out of 46 employed participants and 31 (14.22%) out of 187 unemployed participants had adverse birth outcomes. No association was found between occupation of the participants and adverse birth outcomes ($p = 0.861$).

Table 33: Association between literacy status of the husband of the participant and adverse birth outcomes

Literacy status of Husband	Adverse birth outcomes		Total	p-value
	Present	Absent		
Illiterate	5 (20.83%)	19 (79.17%)	24 (100%)	0.3200 ^{MC}
Primary	3 (7.89%)	35 (92.11%)	38 (100%)	
Secondary	16 (18.18%)	72 (81.82%)	88 (100%)	
College	14 (12.28%)	100 (87.72%)	114 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 3.5481$			df = 3	

Abbreviation: MC: Monte-Carlo's simulation used in Chi-square test

In the present study, out of 24 study participants who had illiterate husbands, five (20.38%) had adverse birth outcomes. Three (7.89%) out of 38, 16 (18.18%) out of 88, 14 (12.28%) out of 114 study participants had adverse birth outcomes, who had husbands with primary, secondary and college level of education respectively. However, literacy status of the husband was not associated with adverse birth outcomes ($p = 0.3200$).

Table 34: Association between occupation of the husband of the participant and adverse birth outcomes

Occupation of Husband	Adverse birth outcomes		Total	p-value
	Present	Absent		
Employed	38 (14.56%)	223 (85.44%)	261 (100%)	0.9995
Unemployed	0 (0%)	3 (100%)	3 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 0.5102$			df = 1	

In the present study, out of 223 participants with employed husbands had adverse birth outcomes and none of the three participants with unemployed husbands had adverse birth outcomes (p = 0.9995). There was no association between occupation of the husband of the participant and adverse birth outcomes.

Table 35: Association between type of family and adverse birth outcomes

Type of Family	Adverse birth outcomes		Total	p-value
	Present	Absent		
Joint	36 (15.52%)	196 (84.48%)	232 (100%)	0.196
Nuclear	2 (6.25%)	30 (93.75%)	32 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 1.96$			df = 1	

In the present study, out of 232 participants living in joint family, 36 (15.52%) study participants had adverse birth outcomes and two (6.25%) out of 32 participants living in nuclear family had adverse birth outcomes. But there was no association between type of family and adverse birth outcomes ($p = 0.196$).

Table 36: Association between socio-economic status and adverse birth outcomes

Socio-economic status	Adverse birth outcomes		Total	p-value
	Present	Absent		
II	5 (8.77%)	52 (91.23%)	57 (100%)	0.4202 ^{MC}
III	15 (14.85%)	86 (85.15%)	101 (100%)	
IV	13 (15.48%)	71 (84.52%)	84 (100%)	
V	5 (22.73%)	17 (77.27%)	22 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 2.799$			df = 3	

Abbreviation: MC: Monte-Carlo's simulation used in Chi-square test

In the current study, five (8.77%) out of 57 study participants belonging to class II socio-economic status had adverse birth outcomes. 15 (14.85%) out of 101, 13 (15.48%) out of 84 and five (22.73%) out of 22 belonging to class III, IV and V socio-economic status respectively, had adverse birth outcomes. However, there was no association between socio-economic status and adverse birth outcomes ($p = 0.4202$).

VII. Association between anthropometric measurements and adverse birth outcomes

Table 37: Association between Body Mass Index and adverse birth outcomes

BMI	Adverse birth outcomes		Total	p-value
	Present	Absent		
Normal	19 (12.5%)	133 (87.5%)	152 (100%)	0.1697 ^{MC}
Underweight	11 (23.91%)	35 (76.09%)	46 (100%)	
Overweight	8 (13.56%)	51 (86.44%)	59 (100%)	
Obese	0 (0%)	7 (100%)	7 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 5.0355$			df = 3	

Abbreviation: MC: Monte-Carlo's simulation used in Chi-square test

In the present study, out of 152 participants with normal BMI, 19 (12.5%) had adverse birth outcomes. 11 (23.91%) out of 46 participants with underweight and eight (13.56%) out of 59 overweight participants had adverse birth outcomes. None of the obese participants had adverse birth outcomes. But no association was found between BMI and adverse birth outcomes (p = 0.1697).

VIII. Association between maternal characteristics and adverse birth outcomes

Table 38: Association between previous bad obstetric history and adverse birth outcomes

Previous bad obstetric history	Adverse birth outcomes		Total	p-value
	Present	Absent		
Present	13 (22.81%)	44 (77.19%)	207 (100%)	0.0410
Absent	25 (12.08%)	182 (87.92%)	57 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 4.1757$				df = 1

In the present study, 13 (22.81%) out of 207 study participants having previous bad obstetric history and 25 (12.08%) out of 57 study participants without previous bad obstetric history had adverse birth outcomes in the present pregnancy. However, there was no association between previous bad obstetric history and adverse birth outcomes ($p = 0.0410$).

Table 39: Association between married life and adverse birth outcomes

Marriage life in years	Adverse birth outcomes		Total	p-value
	Present	Absent		
	3 ± 3	3.73 ± 2.78	3.62 ± 2.82	0.04309 ^w
$\chi^2 = 5165$				

Abbreviations: W: Mann-Whitney test

In the present study, the mean duration of marriage life in years, for those with adverse birth outcomes was 3 ± 3 years and for those without adverse birth outcomes is 3.73 ± 2.78 years. Duration of marriage life in years was higher in participants without adverse birth outcomes. This difference was found to be statistically significant ($p = 0.04309$).

Table 40: Association between respiratory symptoms of the participant and adverse birth outcomes

Health Status	Adverse birth outcomes		Total	p-value
	Present	Absent		
No complaints	13 (13.83%)	81 (86.17%)	94 (100%)	0.2651
Cough with sputum + Ear pain + Sore throat	8 (9.41%)	77 (90.59%)	85 (100%)	
Cough without sputum + Nasal stuffiness	9 (19.15%)	38 (80.85%)	47 (100%)	
Watering of eyes + Cough without sputum	8 (21.05%)	30 (78.95%)	38 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 3.9663$			df = 3	

In the present study, out of 94 study participants without any health complaints, 13 (13.83%) participants had adverse birth outcomes. Eight (9.41%) out of 85 participants with complaints of cough with sputum, ear pain and sore throat, nine (19.15%) out of 47 participants with complaints of cough without sputum and nasal stuffiness and eight (21.05%) out of 38 participants with watering of eyes and cough without sputum had adverse birth outcomes. But there was no association between complaints of respiratory symptoms and adverse birth outcomes ($p = 0.2651$).

Table 41: Association between status of anaemia and adverse birth outcomes

Hb	Adverse birth outcomes		Total	p-value
	Present	Absent		
Normal	17 (14.29%)	102 (85.71%)	119 (100%)	0.9999 ^{MC}
Mild	17 (14.17%)	103 (85.83%)	120 (100%)	
Moderate	4 (16%)	21 (84%)	25 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 0.0585$			df = 2	

Abbreviation: MC: Monte-Carlo's simulation used in Chi-square test

In the current study, 17 (14.29%) out of 119 participants with normal Hb had adverse birth outcomes. 17 (14.17%) out of 120 and four (16%) out of 25 participants with mild and moderate anaemia respectively had adverse birth outcomes. However, there was no association between status of anaemia in the study participant and adverse birth outcomes (p = 0.9999).

IX. Association between housing characteristics and adverse birth outcomes

Table 42: Association between type of roof material and adverse birth outcomes

Roof material	Adverse birth outcomes		Total	p-value
	Present	Absent		
Asbestos	1 (5.26%)	18 (94.74%)	19 (100%)	0.0048
Cement	9 (7.83%)	106 (92.17%)	115 (100%)	
Thatch	28 (21.54%)	102 (78.46%)	130 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 10.6967$			df = 2	

In the current study, one (5.26%) out of 19 study participants having asbestos type of roof, nine (7.83%) out of 115 study participants with cement roof and 28 (21.54%) out of 130 study participants with thatched roof had adverse birth outcomes. The type of roof in the household of the participant was not associated with adverse birth outcomes ($p = 0.0048$).

Table 43: Association between dampness in the household and adverse birth outcomes

Dampness	Adverse birth outcomes		Total	p-value
	Present	Absent		
Absent	7 (6.93%)	50 (87.72%)	101 (100%)	0.0065
Present	31 (19.02%)	176 (80.98%)	163 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 7.3945$			df = 1	

In the present study, 31 (19.02%) out of 163 study participants who had dampness in their household and seven (6.93%) out of 101 study participants who did not have dampness in their household had adverse birth outcomes. Dampness in the household was not associated with adverse birth outcomes (p = 0.0065).

Table 44: Association between overcrowding and adverse birth outcomes

Overcrowding	Adverse birth outcomes		Total	p-value
	Present	Absent		
Absent	7 (12.28%)	50 (87.72%)	57 (100%)	0.6078
Present	31 (14.98%)	176 (85.02%)	207 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 0.2635$			df = 1	

In the current study, seven (12.28%) out of 57 participants living in households with overcrowding and 31 (14.98%) out of 207 participants living in households without overcrowding had adverse birth outcomes. But there was no association between overcrowding and adverse birth outcomes (p = 0.6078).

Table 45: Association between ventilation of the household and adverse birth outcomes

Ventilation	Adverse birth outcomes		Total	p-value
	Present	Absent		
Absent	4 (7.69%)	48 (92.31%)	52 (100%)	0.1245
Present	34 (16.04%)	178 (83.96%)	212 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 2.3602$	df = 1			

In the present study, four (7.69%) out of 52 participants living in ill-ventilated households and 34 (16.04%) out of 212 participants living in well-ventilated households had adverse birth outcomes and, there was no association between ventilation and adverse birth outcomes ($p = 0.1245$).

Table 46: Association between usage of incense sticks and adverse birth outcomes

Usage of incense sticks	Adverse birth outcomes		Total	p-value
	Present	Absent		
No	7 (12.96%)	47 (87.04%)	54 (100%)	0.737
Yes	31 (14.76%)	179 (85.24%)	210 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 0.1128$			df = 1	

In the current study, out of 54 participants who had a habit of using incense sticks, seven (12.96%) had adverse birth outcomes. Out of 210 participants who did not have habit of using incense sticks, 31 (14.76%) had adverse birth outcomes. Usage of incense sticks was not associated with adverse birth outcomes ($p = 0.737$).

Table 47: Association between usage of mosquito coils and adverse birth outcomes

Usage of mosquito coils	Adverse birth outcomes		Total	p-value
	Present	Absent		
No	26 (15.38%)	143 (84.62%)	169 (100%)	0.5408
Yes	12 (12.63%)	83 (87.37%)	95 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 0.3741$			df = 1	

In the present study, out of 169 participants who had habit of using mosquito coils, 26 (15.38%) had adverse birth outcomes. Out of 95 participants who did not have habit of using mosquito coils, 12 (12.63%) had adverse birth outcomes. And, it was found that usage of mosquito coils was not associated with adverse birth outcomes ($p = 0.5408$).

Table 48: Association between cattle shed inside the house and adverse birth outcomes

Cattle shed inside the house	Adverse birth outcomes		Total	p-value
	Present	Absent		
Absent	17 (10%)	153 (90%)	170 (100%)	0.0062
Present	21 (22.34%)	73 (77.66%)	94 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 7.4808$			df = 1	

In the current study, 21 (22.34%) out of 94 who had cattle shed in their household and 17 (10%) out of 170 who did not have cattle shed in their household had adverse birth outcomes. There was no association between cattle shed inside the household and adverse birth outcomes (p = 0.0062).

X. Association between cooking characteristics and adverse birth outcomes

Table 49: Association between windows in the kitchen and adverse birth outcomes

Windows in the kitchen	Adverse birth outcomes		Total	p-value
	Present	Absent		
Absent	18 (20.45%)	70 (79.55%)	88 (100%)	0.0473
Present	20 (11.36%)	156 (88.64%)	176 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 3.9348$	df = 1			

In the present study, 20 (11.36%) out of 176 study participants who had windows in their kitchen and 18 (20.45%) out of 88 who did not have windows in their kitchen had adverse birth outcomes. Windows in the kitchen were not associated with adverse birth outcomes ($p = 0.0473$).

Table 50: Association between cross-ventilation in kitchen and adverse birth outcomes

Cross-ventilation	Adverse birth outcomes		Total	p-value
	Present	Absent		
Absent	29 (18.13%)	131 (81.88%)	160 (100%)	0.0322
Present	9 (8.65%)	95 (91.35%)	104 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 4.5885$	df = 1			

In the present study, 29 (18.13%) out of 160 study participants who did not have cross-ventilation in their kitchen and nine (8.65%) out of 104 study participants who had cross-ventilation in their kitchen had adverse birth outcomes. There was no association between cross-ventilation and adverse birth outcomes ($p = 0.0322$).

Table 51: Association between area of cooking and adverse birth outcomes

Area of cooking	Adverse birth outcomes		Total	p-value
	Present	Absent		
Indoors	32 (12.8%)	218 (87.2%)	250 (100%)	0.0076
Outdoors	6 (42.86%)	8 (57.14%)	14 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 9.7202$			df = 1	

In the current study, 32 (12.8%) out of 250 study participants who had indoor cooking area and six (42.86%) out of 14 who had outdoor cooking area had adverse birth outcomes. No association was found between area of cooking and adverse birth outcomes ($p = 0.0076$).

Table 52: Association between fuel used for cooking and adverse birth outcomes

Fuel used for cooking	Adverse birth outcomes		Total	p-value
	Present	Absent		
Only Wood	1 (14.29%)	6 (85.71%)	7 (100%)	0.0122
LPG + Wood	30 (20.27%)	118 (79.73%)	148 (100%)	
Only LPG	7 (6.42%)	102 (93.58%)	109 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 9.7693$			df = 2	

In the present study, one (14.29%) out of seven study participants who had wood as their cooking fuel, 30 (20.27%) out of 148 who had both wood and LPG as their cooking fuel, and seven (6.42%) out of 109 who had only LPG as their cooking fuel had adverse birth outcomes. However, fuel used for cooking was not associated with adverse birth outcomes ($p = 0.0122$).

Table 53: Association between time spent for cooking breakfast and adverse birth outcomes

Cooking breakfast (in mins.)	Adverse birth outcomes		Total	p-value
	Present	Absent		
	42.76 ± 12.06	36.08 ± 10.89	37.05 ± 11.29	0.00066 ^w
$\chi^2 = 2948$				

Abbreviations: W: Mann-Whitney test

In the present study, the mean duration of cooking breakfast in those with adverse birth outcomes was 42.76 ± 12.06 minutes and for those without adverse birth outcomes is 36.08 ± 10.89 minutes. This difference was found to be statistically significant (p = 0.00066).

Table 54: Association between time spent for cooking lunch and adverse birth outcomes

Cooking lunch (in mins.)	Adverse birth outcomes		Total	p-value
	Present	Absent		
		67.89 ± 19.95	52.3 ± 17.9	54.55 ± 18.98

$\chi^2 = 2360$

Abbreviations: W: Mann-Whitney test

In the present study, mean duration of cooking lunch in those with adverse birth outcomes is 67.89 ± 19.95 minutes and for those without adverse birth outcomes is 52.3 ± 17.9 minutes.

This difference was found to be statistically significant (p = <0.0001).

Table 55: Association between spent for cooking dinner and adverse birth outcomes

Cooking dinner (in mins.)	Adverse birth outcomes		Total	p-value
	Present	Absent		
		65.92 ± 18.3	50.77 ± 16.42	52.95 ± 17.49

$\chi^2 = 2357.5$

Abbreviations: W: Mann-Whitney test

In the present study, mean duration of cooking dinner in those with adverse birth outcomes is 65.92 ± 18.3 minutes and for those without adverse birth outcomes is 50.77 ± 16.42 minutes. This difference was found to be statistically significant (p = <0.0001).

Table 56: Association between total time spent in kitchen for cooking and adverse birth outcomes

Cooking duration (in hours)	Adverse birth outcomes		Total	p-value
	Present	Absent		
		2.94 ± 0.75	2.32 ± 0.68	2.41 ± 0.72

$\chi^2 = 2258$

Abbreviations: W: Mann-Whitney test

In the current study, mean cooking duration for those with adverse birth outcomes is 2.94 ± 0.75 hours and for those without adverse birth outcomes is 2.32 ± 0.68 hours. This difference was found to be statistically significant (p = <0.0001).

Table 57: Association between ranges of household PM_{2.5} concentrations in household and adverse birth outcomes

PM _{2.5} /mm ³ concentrations	Adverse birth outcomes		Total	p-value
	Present	Absent		
≤ 40	2 (3.64%)	53 (96.36%)	55 (100%)	0.0147
41-79	7 (11.86%)	52 (88.14%)	59 (100%)	
≥ 80	29 (19.33%)	121 (80.67%)	150 (100%)	
Total	38 (14.39%)	226 (85.61%)	264 (100%)	
$\chi^2 = 8.4418$			df = 2	

In the present study, two (3.64%) out of 55 study participants with less than or equal to 40/mm³ PM_{2.5} concentration in their households, seven (11.86%) out of 59 of those who had 41-79/mm³ PM_{2.5} concentration in their households, and 29 (19.33%) out of 150 of those with 80/mm³ or more PM_{2.5} concentration in their households had adverse birth outcomes. There was no association between ranges of household PM_{2.5} concentrations and adverse birth outcomes (p = 0.0147).

Table 58: Association between mean 24-hour PM_{2.5} concentration and adverse birth outcomes

PM _{2.5} /mm ³	Adverse birth outcomes		Total	p-value
	Present	Absent		
	178.96 ± 90.14	113.29 ± 84.33	122.74 ± 88.09	<0.0001 ^w
$\chi^2 = 2529$				

Abbreviations: W: Mann-Whitney test

In the present study, mean PM_{2.5} concentration of the study participants with adverse birth outcomes was 178.96 ± 90.14/mm³ and for those without adverse birth outcomes was 113.29 ± 84.33/mm³. The mean 24-hour PM_{2.5} concentration was higher in households of the participants with adverse birth outcomes. This difference was found to be statistically significant (p = <0.0001).

XI. Association of various characteristics and PM_{2.5} concentrations in household

Table 59: Association of household characteristics and mean PM_{2.5} concentrations in the household

Household characteristics		Mean PM _{2.5} concentration	p-value
Roof material	Thatch	159.67 ± 88.39	<0.0001*
	Asbestos	112.33 ± 67.51	
	Cement	82.71 ± 71.79	
Dampness	Present	145.61 ± 89.21	<0.0001*
	Absent	85.24 ± 72.74	
Overcrowding	Present	131.8 ± 87.49	0.00018*
	Absent	89.82 ± 82.97	
Ventilation of the house	Adequate	74.16 ± 71.43	<0.0001*
	Inadequate	134.66 ± 87.84	
Cattle shed inside the house	Present	175 ± 83.83	<0.0001*
	Absent	93.85 ± 76.49	
Domestic animals inside the house	Present	140.13 ± 85.26	0.0002*
	Absent	108.25 ± 88.08	

Usage of incense sticks	Yes	124.06 ± 87.61	0.4235
	No	117.62 ± 90.6	
Usage of mosquito coils	Yes	128.26 ± 88.09	0.3025
	No	119.64 ± 88.2	

In the present study, the mean PM_{2.5} concentration was found to be lesser in households of the participants with asbestos and cement roof when compared to households with thatched roof ($p = <0.0001$). Households of the participants with presence of dampness, and ill-ventilation were associated with higher mean PM_{2.5} concentrations ($p = <0.0001$).

Households of the participants with overcrowding showed higher mean PM_{2.5} concentrations when compared to the households without overcrowding ($p = 0.00018$). The mean PM_{2.5} concentrations were higher among participants who had domestic animals in their households when compared to those who did not have domestic animals in their household ($p = 0.0002$).

Factors such as usage of incense sticks and mosquito coils were not associated with PM_{2.5} ($p = 0.4235$ and 0.3025 respectively).

Table 60: Association of kitchen characteristics and mean PM_{2.5} concentrations in the household

Kitchen characteristics		Mean PM_{2.5} concentrations	p-value
Windows in the kitchen	Present	105.02 ± 85.1	<0.0001*
	Absent	158.19 ± 83.58	
Doors open while cooking	Yes	122.58 ± 87.71	0.8122
	No	133.1 ± 126.35	
Cross-ventilation	Present	82.34 ± 76.91	<0.0001*
	Absent	149 ± 85.11	
Smoke outlet / Exhaust fan in the kitchen	Present	83.82 ± 78.83	<0.0001*
	Absent	131.83 ± 87.83	
Presence of soot in the kitchen wall	Present	135.65 ± 87.46	<0.0001*
	Absent	80.69 ± 76.84	

In the present study, the mean PM_{2.5} concentrations were found to be higher in the households of the participants if there were no windows in the kitchen when compared to the households of the participants with windows in their kitchen ($p = <0.0001$). Absence of cross-ventilation and smoke outlet / exhaust fan in the kitchen was associated with higher mean PM_{2.5} concentrations ($p = <0.0001$). The mean PM_{2.5} concentrations was higher among the households of the participants who had presence of soot in the kitchen wall when compared to the households of the participants without soot in the kitchen wall ($p = <0.0001$).

Table 61: Association of cooking fuel characteristics and mean PM_{2.5} concentrations in the household

Cooking characteristics		Mean PM _{2.5} concentrations	p-value
Involved in cooking at present	Yes	122.05 ± 87.64	0.6469
	No	132.81 ± 96.72	
Fuel used for cooking	LPG + Wood	159.54 ± 82.57	<0.0001*
	Only LPG	65.57 ± 54.59	
	Only Wood	234.83 ± 109.82	
Type of stove used for cooking	LPG stove + Chula	163.36 ± 83.26	0.005998*
	LPG stove	67.3 ± 52.1	
	Chula	239.83 ± 102.66	

In the current study, participants who preferred wood alone or used together with LPG as cooking fuel had higher PM_{2.5} concentrations in their households when compared to households of participants who preferred only LPG as their cooking fuel ($p = <0.0001$). The mean PM_{2.5} concentrations were higher in households of the participants who preferred chula alone or used together with LPG stove, for cooking when compared to the participants who used only LPG stove for cooking ($p = 0.005998$).

Table 62: Univariate logistic regression analysis of risk factors associated with adverse birth outcomes

Risk factors causing adverse birth outcomes		UOR (95% CI)	p-value
Previous bad obstetric history	No	1	
	Yes	2.1509 (1.0265, 4.4844)	0.044
Roof material	Asbestos	1	-
	Cement	1.5283 (0.2628, 29.0411)	0.6957
	Thatch	4.9412 (0.9539, 90.8045)	0.1279
Dampness	Absent	1	-
	Present	3.1536 (1.4045, 8.0696)	0.009
Cattle shed inside the house	Absent	1	-
	Present	2.58904 (1.2921, 5.2593)	0.0075
Windows in the kitchen	Absent	1	-
	Present	0.4985 (0.2479, 1.0068)	0.05425
Cross-ventilation	Absent	1	-
	Present	0.42795 (0.1836, 0.9129)	0.036

Area of cooking	Indoors	1	-
	Outdoors	5.1093 (1.5917, 15.6646)	0.0044
Total cooking duration (in hours)		2.9120 (1.8577, 4.6644)	<0.0001*
Indoor Air pollution	Absent	1	-
	Present	5.5144 (1.6092, 34.6352)	0.022*

Abbreviation: UOR: Unadjusted Odds Ratio; CI: Confidence Interval

In the current study, univariate logistic regression analysis indicated that high PM_{2.5} concentrations and prolonged total cooking duration were associated with adverse birth outcomes. For every unit increase in the total cooking duration, the participants had 2.912 [95% CI: (1.8577, 4.6644)] times more likely chance of having adverse birth outcomes. Specifically, the chances of adverse birth outcomes was five times more likely in study participants exposed to indoor air pollution [95% CI: (1.0416, 1.1239)].

Factors such as having previous bad obstetric history, household characteristics such as living in household with hatch or asbestos type of roof material, presence of dampness in the house, presence of cattle shed, and cooking characteristics like absence of windows and cross-ventilation in the kitchen and area of cooking were not significantly associated with adverse birth outcomes ($p > 0.05$).

Table 63: Multivariate logistic regression analysis of Risk factors causing adverse birth outcomes

Risk factors causing adverse birth outcomes		AOR (95% CI)	p-value
Previous bad obstetric history	No	1	
	Yes	1.6882 (0.7002, 3.9545)	0.2324
Dampness	Absent	1	
	Present	1.4786 (0.3733, 5.8254)	0.5746
Cattle shed inside the house	Absent	1	
	Present	0.9825 (0.3953, 2.4241)	0.9694
Cross-ventilation	Absent	1	
	Present	0.7859 (0.2647, 2.2624)	0.657
Area of cooking	Indoors	1	-
	Outdoors	2.7155 (0.6339, 11.7783)	0.1729
Total cooking duration (in hours)		2.1417 (1.1556, 4.0617)	0.0168*
Indoor Air pollution	Absent	1	-
	Present	1.7046 (0.3231, 13.144)	0.5559

Abbreviation: AOR: Adjusted Odds Ratio; CI: Confidence Interval

In the present study, after adjusting for maternal age, BMI, Haemoglobin level, and previous obstetric history, multivariate logistic regression analysis revealed that adverse birth outcomes were influenced by total duration of cooking (p = 0.0168). With increase in the

total duration of cooking, the chances of having adverse birth outcomes increased by 2.1417 times [95% CI: (0.3231, 13.144)].

Factors such as previous bad obstetric history of the participant, presence of dampness in the household, presence of cattle shed inside the household, having a household without cross-ventilation, area of cooking and exposure to indoor air pollution did not show significant association with adverse birth outcomes ($p > 0.05$).

Table 64: Multiple Linear Regression analysis for adverse birth outcomes per every 10 $\mu\text{g}/\text{mm}^3$ of $\text{PM}_{2.5}$ concentration

Adverse birth outcome per 10 $\mu\text{g}/\text{mm}^3$	p-value
1.07892 (95% CI 1.0377,1.1234)	0.00016*
Change in Birth weight per 10 $\mu\text{g}/\text{m}^3$ (95% CI)	p-value
6.623 (95% CI -11.5899, -1.6554)	0.00917*

Abbreviation: CI: Confidence Interval

In the present study, multiple linear regression analysis showed that, after adjusting for maternal age, BMI, Haemoglobin level, and previous obstetric history, for per unit increase in $\text{PM}_{2.5}$ concentration, the chances of having an adverse birth outcome significantly increased 1.07892 [95% CI (1.0377, 1.1234)] times.

Similarly, with per unit increase in maternal $\text{PM}_{2.5}$ exposure, there was a reduction in the birth weight of the new-born by 6.623 gm (95% CI: 1.6554-11.5899).

Discussion:

Indoor air pollution is an environmental hazard and maternal exposure to indoor air pollution gives rise to deteriorating effects on maternal and foetal health. The implications of indoor air pollution on pregnancy is a concern worldwide, specifically in countries like India, where the susceptibility to factors causing indoor air pollution is much more. Research has hinted an elevated risk of adverse birth outcomes such as low birth weight, abortions, stillbirths and preterm births. The total national disease burden due to indoor air pollution accounts to 6% in India, in which adverse birth outcomes constitute to majority of the premature deaths.¹⁸ The energy progress report (IEA, IRENA, UNSD, World Bank, WHO), 2024, estimates 1.8 billion population globally will lack the access to healthy fuels and technologies even by the year 2030.¹²

So, it is deemed necessary to improve resources among communities, like rural populations and slums, who either do not have access to healthier cooking fuels or do not understand the healthy practices and living standards that promote good and harmless indoor air quality.

Table 1- 8: Socio demographic profile of study participants

In the present study, the mean age of the study participants is 24.45 ± 4.29 . Almost three-fourths (74.24%) of the participants belonged to the age group of 20-30 years. This is in line with an epidemiological study where 73.3% of the participants were less than 30 years of age.⁴⁷

In the present study, 90% of the participants were Hindus which is similar to study conducted in South-India where 93% of that study participants were Hindus.²⁵

Only 9% of the present study participants' husbands were illiterate which is comparatively similar to a study conducted in Uganda where majority of them were literates.⁴⁷

In the present study, it was found that majority (82.95%) of the participants were housewives, among whom, only 6% were illiterates and one-third (23.11%) of the study participants attained primary education and three-fourths of the study participants belonged to lower-middle or lower socio-economic status (SES), all of which are in line with previous studies.^{37, 25, 41, 28, 48}

Table 9: Sources of Indoor air pollution among study participants

In the present study, none of the study participants were current smokers. Similar studies done in Zambia and South Africa had shown 3.6% and 3.1% participants respectively, implying that current smokers in pregnant women were not common.^{48, 30}

In the current study, 42.8% of the participants had passive smoking history which is in similarity with the studies done in South-Africa and Los Angeles.^{30, 26}

79.5% of the present study participants had habit of usage of incense sticks and 35.9% of them had habit of usage of mosquito coils, similar to studies done in Karnataka which showed their study participants having regular usage of incense sticks and mosquito coils as 90% and 45.4% respectively.^{37, 50}

In the present study, with regards to fuel used for cooking, 56.06% of the study participants used both liquid petroleum gas (LPG) and wood, 41.29% of the study participants used only liquid petroleum gas and only 2.65% of the study participants used only wood, which is similar to a study done in Adama of Ethiopia where 48.4% participants used LPG or electricity, 78.6% used LPG along with either wood or charcoal and 4% used only LPG.³⁶

Table 10 - 13: Previous obstetric history and outcomes of present pregnancy in study participants

In the present study, more than three-fourths of the study participants did not have any previous history of bad obstetric outcomes whereas, 7.5% had history of low birth weight, 12.5% of the study participants had history of abortions and only 0.7% had history of preterm births in previous pregnancies and these findings are almost similar to an epidemiological study done in South Asia.³⁸

In the current study, 10.2% of the study participants delivered low birth weight babies and 3.7% had pre-term births in their present pregnancy which is in line to a study done in South Asia.²¹

In the current study, 77.7% of the study participants had normal vaginal delivery and 22.35% of the study participants delivered through lower section caesarean delivery, similarly to a study done in Ghana which showed 90.1% and 9.9% of their participants had normal vaginal delivery and lower section caesarean delivery.³²

Table 14: Respiratory symptoms among study participants

In the present study, 17.8% of the study participants had cough along with nasal stuffiness, 32.2% had ear pain and sore throat and 14.3% had watering of the eyes and these findings are similar to a community-based study conducted in Karnataka.⁵⁰

Table 15: Anaemia in study participants

In the current study, 54.92% of the study participants were anaemic which was in line with a study done in Gujarat which had 16% of the study participants to be anaemic.²⁰

Table 16: BMI of study participants

In the present study, the mean BMI of 264 study participants was 22.12 ± 3.92 , and even though there were 57.58% of the study participants who were normal weight, 17.42% of the study participants were underweight, 22.35% and 2.65% of the study participants were overweight and obese respectively. These were similar to a South Asian study that showed 17.6% participants were underweight, 20.6% were overweight and obese.³⁸

Table 17 - 22: Housing characteristics among study participants

In the current study, 45.08% of the study participants were living in pucca households, 54.17% of them were living in semi-pucca households and 0.76% were living in kuccha households, similar to the study done in Tamil Nadu which showed 49.9% of the participants were living in pucca houses and 27.2% were living in semi-pucca households.²⁸

Among the present study participants 43.56% lived in houses with cemented roofs and 61.74% of the study participants had dampness in their households which is similar to previous studies which showed 74% of the participants living in cement roofed households and 19.4% of the participants having dampness in their households due to humid conditions.^{47, 50}

78.41% of the present study participants were living in households with overcrowding and 80.3% of the study participants were living in ill-ventilated households and these findings were similar to study done in Uganda where 78.4% participants were living in ill-ventilated households and the study done in Karnataka had 31.5% participants living in households with overcrowding.^{50, 47}

Table 23: PM_{2.5}/m³ concentrations in households of the participants

In the present study, 20.83% of the study participants had household PM_{2.5} concentrations ranging 40 µg/m³ or less and more than half (56.82%) of the study participants were living in households with PM_{2.5} concentrations ranging 80 µg/m³ or more which was

similar to a study conducted in China where 44.37% participants were living in households with PM_{2.5} concentrations ranging 80 µg/m³ or more.³¹

Table 24 to 27: Cooking characteristics among study participants

In the current study, 70.83% of the total study participants had a separate room as kitchen, 6.06% and 17.8% of the total study participants used a living or sleeping room with partition and without partition respectively, and 4.55% used outdoors for cooking purposes. Similarly, a study from Nepal showed 69.9% of the participants had a separate room as kitchen and another study conducted in India showed similar findings regarding area of cooking where 29% of the participants had separate kitchen, 275 participants did not have separate kitchen and 9% used outdoors for cooking area.^{49, 19} Whereas another study conducted in Zambia showed 20.3% of the participants using outdoors for cooking purposes.⁴⁸

In the present study, 39.39% of the total study participants had cross-ventilation in their kitchen and this finding is similar to a Sri Lankan study where 30.05% had no cross-ventilation in their kitchen.^{24, 47}

Majority (93.56%) of the present study participants were involved in cooking at the time of study and the reason for choice of fuel among one-fourth (24.62%) of the total study participants was because they were habituated to their Energy source or fuel preferred for cooking and half (51.14%) of the participants used LPG because of government supply. These findings were similar to the Uganda study where the participants' reason for choice of cooking fuel was because of habituation and affordability.⁴⁷

Table 28: Exposure to Indoor air pollution and adverse birth outcomes among study participants

In the present study, 79.1% of the total study participants had exposure to indoor air pollution and 14.3% participants had adverse birth outcome in their present pregnancy similar to a study done in Sri Lanka where 80.7% participants had exposure to indoor air pollution and 20.5% of study participants had adverse birth outcomes.²⁴

Table 29 - 36: Association between socio-demographic profile and adverse birth outcomes

In the present study, the socio-demographic characteristics of study participants such as age, religion, literacy status and occupation of the study participants, literacy status and occupation of husbands of the study participants, type of family and socio-economic status, were found not to be associated with adverse birth outcomes. Similarly, studies done in Karnataka and China have not found any association between age, literacy and occupation status with adverse birth outcomes.^{46, 31} In addition to this, no association was found between socio-economic status of the participants and adverse birth outcomes in a Massachusetts study.³⁹ Even though, there were two studies that did not find any association between literacy status, occupation and socio-economic status of the mother, but found significant association between increasing age of the mother and adverse birth outcomes.^{42, 30} However, studies done in Gujarat and South-Africa found that lower socio-economic class was associated with adverse birth outcomes suggesting the lack of proper living conditions, inadequate antenatal and nutritive care.^{20, 41} And, a study in California showed an association between lesser education of the husbands of the participants and adverse birth outcomes.⁴⁵

Table 37: Association between BMI and adverse birth outcomes

In the current study, no association was found between the BMI of the study participants and adverse birth outcomes. This finding aligns with previous studies, some of

which have in contrary, identified gestational weight gain as a risk factor for adverse birth outcomes.^{38, 20, 41, 46} But, studies done in Tamil Nadu and South-Africa found association between maternal BMI and adverse birth outcomes, indicating that high maternal BMI was a risk factor for low birth weight, abortions and preterm births.^{28, 30} However, none of these studies have explored the potential mechanisms behind the presence or absence of an association between maternal BMI and adverse birth outcomes.

Table 38 - 41: Association between maternal characteristics and adverse birth outcomes

In the current study, a history of adverse obstetric outcomes was found to be associated with negative birth outcomes ($p = 0.04$), consistent with previous research.^{20, 29, 32, 46} Several factors could explain this finding, including short inter-pregnancy intervals, undiagnosed underlying conditions, and chronic exposure to $PM_{2.5}$ or any contributing factors leading to indoor air pollution. While participants with any known disease conditions or comorbidities were excluded from the study, undiagnosed pathologies, which may have been unknown to the participants themselves, cannot be entirely ruled out.

In the present study, the mean duration of married life of the study participants in years is 3.62 ± 2.82 and it was found that shorter duration of married life among the study participants is associated with adverse birth outcomes. Contrary to this finding, previous studies did not find any association between duration of married life and adverse birth outcomes.^{42, 29, 31}

Table 42 - 48: Association between housing characteristics and adverse birth outcomes

The present study found that study participants living in households, with thatched roofs, with presence of dampness and, presence of domestic animals or cattle shed, were found not to be associated with adverse birth outcomes than those participants without these household characteristics. These findings are in contrary with various previous studies.^{27, 42, 50}

In the current study, study participants living in over-crowded and ill-ventilated households were not associated with adverse birth outcomes, however, there are few prior studies that have shown a significant association with regards to overcrowding and ventilation, implying that participants living in households with over-crowding and ill-ventilation were more associated with adverse birth outcomes.^{28, 27, 47}

Table 49 - 56: Association between cooking characteristics and adverse birth outcomes

In the present study, study participants who did not have windows in their kitchen were associated with more adverse birth outcomes when compared to the participants who had windows in their kitchen ($p = 0.0473$). This finding aligns with the study conducted in Uganda.⁴⁷

In the current study, absence of cross-ventilation was associated with adverse birth outcomes ($p = 0.0322$), which is similar to studies conducted in Karnataka, Sri Lanka, Nepal, Ghana and China.^{37, 24, 49, 32, 40} The reason that can be attributed to this association is that, in the absence of cross-ventilation, there is minimum flow of particulate matter or any possible pollutants that can lead to poor indoor air quality which can lead to high risk of adverse birth outcomes in participants who are exposed to such kitchen characteristics, when compared to participants who have adequate flow of air in their kitchen and better cooking conditions.

The present study found that the study participants who had wood and liquid petroleum gas as their choice of cooking fuel were significantly associated with adverse birth outcomes when compared to study participants who preferred only liquid petroleum gas for cooking purposes ($p = 0.0122$). This finding is supported by previous research where various studies.^{25, 23, 21, 22, 24, 27, 29, 32} Studies conducted in Peru and California have implicated that preference of biomass as cooking fuel is a major risk factor for adverse birth outcomes in the exposed participants, when compared to the participants who use safer cooking fuels.^{44, 45}

Among the current study participants, the mean durations for cooking breakfast, lunch and dinner, were 37.05 ± 11.29 , 54.55 ± 18.98 and 52.95 ± 17.49 respectively. The mean durations for cooking breakfast ($p = 0.00066$), lunch ($p = <0.0001$) and dinner ($p = <0.0001$), were found to be higher in the study participants with adverse birth outcomes and this association was significant, which aligns in similarity with the Ghana study.³²

The present study found that the total time spent for cooking was significantly higher in study participants with adverse birth outcomes ($p = <0.0001$). This finding is consistent to the study conducted in Ndola and Masaiti of Zambia.⁴⁸

Table 57 - 58: Association of household PM_{2.5} concentrations and adverse birth outcomes

In the current study, the study participants exposed to household PM_{2.5} concentrations of $40 \mu\text{g}/\text{m}^3$ or higher were associated with adverse birth outcomes and the risk increased even more among the study participants when household PM_{2.5} concentrations elevated to $80 \mu\text{g}/\text{m}^3$ or more. The mean 24-hour PM_{2.5} concentration was found to be significantly higher among study participants with adverse birth outcomes than the participants without adverse birth outcomes ($p = <0.0001$). These findings were similar to many studies that demonstrated significant association between elevated PM_{2.5} concentrations and adverse birth outcomes, and furthermore, these studies suggest that PM_{2.5} concentrations exceeding the acceptable standards are direct contributors to indoor air pollution, which can affect the normal physiological development of fetus.^{21 – 27, 35, 36, 38, 29}

In the present study, no association was found between usage of incense sticks or mosquito coils and adverse birth outcomes. In contrast to this finding, a study conducted in South India found the habit of regular incense stick use as a risk factor for adverse birth outcomes, although no association was found between the use of mosquito coils and adverse birth outcomes.³⁷

Table 59: Association between household characteristics and mean PM_{2.5} concentrations

The present study found that households with thatched roof and the presence of dampness was associated with higher PM_{2.5} concentrations which is consistent to previous studies conducted in Karnataka and Uganda, both of which indicated that these characteristics contributed to indoor air pollution.^{47, 50}

The current study showed higher PM_{2.5} concentrations in households with overcrowding and inadequate ventilation. Similarly, studies conducted in China and South Asia have shown that overcrowded and ill-ventilated households were significantly associated with high PM_{2.5} concentrations.^{40, 38}

However, the present study found no significant association between history of incense sticks use or history of mosquito coils use and high concentrations of PM_{2.5} which was in contrary as per two different studies carried out in rural communities of Karnataka where, both of the studies established high PM_{2.5} concentrations in the households with habit of incense sticks use and mosquito coils use.^{37, 50}

Table 60: Association between kitchen characteristics and mean PM_{2.5} concentrations

The present study found that households without windows in their kitchens were significantly associated with high PM_{2.5} concentrations ($p = <0.0001$), while no significant association was found between closed kitchen doors during cooking and high PM_{2.5} concentrations. However, the Uganda study showed significant associations between both the absence of windows in the kitchen and closed doors in the kitchen during cooking, and high PM_{2.5} concentrations.⁴⁷

In the current study, absence of both, cross-ventilation and smoke outlet or exhaust fan in the kitchen, and presence of soot in the kitchen wall were associated with high PM_{2.5}

concentrations ($p = <0.0001$). These findings are similar to previous studies conducted in India, Sri Lanka and Ghana.^{37, 38, 24, 42, 32}

According to previous research studies, the mechanism linking any of the household characteristics or kitchen characteristics or both to indoor air pollution is, insufficient airflow exchange within the household, compounded by factors such as unhygienic environments and overcrowding. These conditions cause particulate matter to become stagnant in a closed living space, leading to elevated mean $PM_{2.5}$ concentrations that ultimately causes the members of the household susceptible to indoor air pollution exposure.

Table 61: Association between cooking fuel characteristics and mean $PM_{2.5}$ concentrations

In the present study, study participants' involvement in cooking during the period of their current pregnancy is not associated with higher mean $PM_{2.5}$ concentrations. Whereas previous studies have shown association between involvement in cooking to high levels of $PM_{2.5}$ concentrations.²⁶

The current study found significant association between biomass fuel and chula as choice for cooking purposes and high mean $PM_{2.5}$ concentrations. The study participants who preferred wood alone or along with liquid petroleum gas ($p = <0.0001$) and chula ($p = 0.005998$) for cooking were exposed to $PM_{2.5}$ concentrations above the acceptable standards. This finding adds evidence to literature since many studies conducted all over the world, which aimed at determining association between preference of biomass fuel for cooking and indoor air pollution through elevated $PM_{2.5}$ concentrations have shown similar findings.^{25, 21, 22, 24, 47, 48}

Table 62: Multivariate logistic regression analysis

In the present study, multivariate logistic regression analysis revealed that adverse birth outcomes were influenced by total duration of cooking. This finding was similar to a study conducted in Ndola and Masaiti of Zambia, that showed an association between time spent for cooking and adverse birth outcomes but the same study also showed an association between higher mean PM_{2.5} concentrations indicating indoor air pollution and adverse birth outcomes.⁴⁸

The current study did not find any association between factors such as a participant's previous bad obstetric history, the presence of dampness in the household, the presence of cattle shed inside the household, having a household without cross-ventilation, the area of cooking and exposure to indoor air pollution with adverse birth outcomes. However, a study conducted in Peru found a significant association between high PM_{2.5} concentrations and adverse birth outcomes.⁴⁴

Many studies have shown that participants using biomass fuel for cooking purposes were significantly associated with adverse birth outcomes, and a few studies concluded that the use of biomass contributes to indoor air pollution.^{25, 21, 22, 24, 47, 48}

Additionally, a few studies conducted in, Karnataka, Sri Lanka, Africa, Ghana and South Africa, implied that elevated PM_{2.5} concentrations, indicating indoor air pollution, were a major risk factor for adverse birth outcomes.^{19, 21, 24, 30, 32} Literature suggests that gestational PM_{2.5} exposure, independent of the trimester, disrupts the cardiovascular physiology critical for the morphology of umbilical cord, leading to artery dilation and maternal oxidative distress damaging the placental barrier and impairing the nutritional supplementation required for the development of fetus.⁴⁵

However, the study conducted in Adama of Ethiopia showed similar findings to the present study which could not find conclusive evidence for an association between indoor air pollution and adverse birth outcomes.³⁶

Also, a study conducted among 204 countries found that a previous bad obstetric history is a risk factor for adverse birth outcomes in the present pregnancy, and the reason could be attributed to chronic exposure to indoor air pollution, given that physiological and pathological conditions were ruled out.²⁹

Although, a study of Massachusetts indicated factors such as lower class of socio-economic status, overcrowded households, inadequate ventilation in a household, absence of cross-ventilation in kitchen to be contributors of indoor air pollution which are major risk factors for adverse birth outcomes.³⁹

Table 63: Multiple Linear Regression analysis for adverse birth outcomes per every 10 $\mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$ concentration

In the present study, after adjusting for maternal age, BMI, Haemoglobin level, and previous obstetric history, multiple linear regression analysis showed that, for every increase in 10 $\mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$ concentration, the chances of having an adverse birth outcome significantly increased 1.07 times and this finding is consistent with many previous studies that showed risk of adverse birth outcomes increasing with higher $\text{PM}_{2.5}$ concentrations. A study in Tamil Nadu found that a 10 $\mu\text{g}/\text{m}^3$ increase in maternal $\text{PM}_{2.5}$ exposure was associated with 2% increase in prevalence of adverse birth outcomes.²⁸

Similar to the present study finding, a study conducted in South Asia revealed each 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ concentration was associated with 1.08 times higher chance of adverse birth outcomes.⁴²

The current study showed additionally found that with every increase in $10 \mu\text{g}/\text{m}^3$ of maternal $\text{PM}_{2.5}$ exposure, there was a reduction in the birth weight of the new-born by 6.623 gm. This finding aligns with the study conducted in Peru that showed a 8.13 gm decrease in low birth weight with each increase in $10 \mu\text{g}/\text{m}^3$ concentration of $\text{PM}_{2.5}$ exposure.⁴⁴

Furthermore, numerous studies conducted in Peru, California, Sri Lanka, Africa, China and India concluded that maternal exposure to any factors causing indoor air pollution that led to elevated concentrations of $\text{PM}_{2.5}$, increased the risk of adverse birth outcomes.^{35, 21, 24, 26, 31, 44, 45}

Strengths:

PM_{2.5} concentrations was measured in all households for 24 hours.

The PM_{2.5} concentrations were measured using a standard air quality monitoring device that has an optimum PM_{2.5} sensor.

The average PM_{2.5} concentrations from continuous 24-hour measurements for a household were calculated using appropriate Python coding for accurate values.

The study participants were enrolled regardless of their trimester, without being restricted to a specific time period, which could have limited the adverse birth outcomes to that particular trimester.

Limitations:

Since the current study uses a longitudinal design, causality between indoor air pollution and adverse birth outcomes could not be established.

The air quality monitoring device could only measure PM_{2.5} concentrations, but measuring additional indoor air pollutants such as CO (Carbon monoxide), VOC (Volatile Organic Compounds), SO₂ (Sulphur dioxide) and others would have provided added benefit, and contributed to more conclusive evidence.

Recommendations:

Although health programs are promoting safer and healthier cooking fuels, biomass continues to be prevalent in many communities, and the plausible reasons for failure of these strategies include inadequate interventions aimed at replacing biomass with cleaner fuels, or the inability of the target population to transition to healthier alternatives.

To address the problem, qualitative research could be used to explore the reasons behind specific risk groups' resistance to adopting healthier practices, as well as to assess the effectiveness and impact of current interventions.

Qualitative research could help uncover underlying issues and guide more successful strategies.

Culturally sensitive interventions are essential to raise awareness about the importance of air quality, promote healthier living standards, and provide education on maternal health, as well as the physiological and pathological changes caused by indoor air pollution.

Conclusion:

In the current study, out of the total 264 participants, majority (79.1%) of the participants were exposed to indoor air pollution.

14.3% of the total study participants had adverse birth outcomes.

In the present study, after adjusting for maternal age, BMI, Haemoglobin level, and previous obstetric history, it was revealed that adverse birth outcomes were influenced by total duration of cooking. It was found that, with increase in the total duration of cooking, the chances of having adverse birth outcomes increased by 2.1417 times. Factors such as previous bad obstetric history of the participant, presence of dampness in the household, presence of cattle shed inside the household, having a household without cross-ventilation, area of cooking and exposure to indoor air pollution did not show significant association with adverse birth outcomes.

In the present study, for every per unit increase in $PM_{2.5}$ concentration, the chances of having an adverse birth outcome significantly increased 1.07892 times.

And it was also found that, with per unit increase in maternal $PM_{2.5}$ exposure, there was a reduction in the birth weight of the new-born by 6.623 gm.

Summary:

The present study was a longitudinal study undertaken to determine the association between maternal exposure to indoor air pollution and adverse birth outcomes. The study included a total of 264 participants, that is, pregnant women residing in a rural field practice area of Department of Community Medicine, Jawaharlal Nehru Medical College, Belagavi, and the participants were chosen using simple random sampling method. Duration of the study was from 1st April 2023 to 31st March 2024. Study participants were enrolled after taking their written informed consent and were interviewed using a pretested and pre-designed questionnaire. 24 hour measurements of PM_{2.5} concentrations were measured using a standardized tool, Atmos air quality monitoring device. The participants were then followed up after the outcome of their pregnancy.

In the present study, a total of 264 pregnant women participated with nearly half of the participants (46.59%) aged between 25 - 30 years and majority (90.15%) being Hindus. One-third of the study participants attained primary education and most of the participants (82.95%) were housewives. Majority (88.26%) of the participants lived in a nuclear family and 38.26% belonged to socio-economic class III.

More than half (56.06%) of the participants preferred both liquid petroleum gas and wood for cooking purposes. Among the 264 study participants, majority (79.1%) of them were exposed to indoor air pollution and 14.3% of the total study participants experienced adverse birth outcomes. More than half (56.82%) of the study participants were living in households with PM_{2.5} concentrations exceeding 80 µg/m³ or more.

The current study found that factors such as a longer duration of marriage for the participants, participants' previous history of bad obstetric outcomes, thatched roofing in the household, the presence of dampness in the household, absence of windows in kitchen, absence of cross-

ventilation in kitchen, the area of cooking, the type of cooking fuel used, prolonged duration of cooking, and the mean 24-hour concentrations of PM_{2.5} were associated with adverse birth outcomes.

After adjusting for maternal age, BMI, Haemoglobin level, and previous obstetric history, the present study findings revealed that adverse birth outcomes were influenced by total duration of cooking. The participants were 2.1417 times more likely to have adverse birth outcomes with unit increase in total time spent of cooking. Factors such as previous bad obstetric history of the participant, presence of dampness in the household, presence of cattle shed inside the household, having a household without cross-ventilation, area of cooking and exposure to indoor air pollution did not show significant association with adverse birth outcomes.

The present study also revealed that, for every increase in 10 µg/mm³ of PM_{2.5} concentration, the chances of having an adverse birth outcome significantly increased 1.07892 times. Similarly, with every increase in 10 µg/mm³ of maternal PM_{2.5} exposure, there was a reduction in the birth weight of the new-born by 6.623 gm.

Based on the results of this study, there are several contributing factors that can cause indoor air pollution and maternal exposure to indoor air pollution is a major risk factor for adverse birth outcomes.

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ANNEXURE - I

INFORMED CONSENT FORM

Introduction: You are being invited to participate in this study to find out “Maternal exposure to indoor air pollution and birth outcome - a longitudinal study”. Indoor air pollution is a major constituent of health disorders in the world and even in India. Various lifestyle practices that lead to indoor air pollution are the causes of major disease burden especially to women. Pregnant women are at much higher risk and indoor air pollution poses as a threat to both mother and the fetus. There is limited research regarding adverse pregnancy outcomes in pregnant women exposed to indoor air pollution. Hence the present study is undertaken. Participation in this study is completely voluntary.

Explanation of procedure: In this study, you will have to answer a few prepared questions about sociodemographic variables, maternal health characteristics, general household characteristics, kitchen characteristics, type of fuel used for cooking, various sources of indoor air pollution and birth outcomes such as preterm, full term, still births, abortions etc., will be collected. A device measuring indoor air pollution will be placed in your kitchen for 24 hours. If you agree to participate, then only the questions will be asked to you and the device will be placed in your home. At any moment you can withdraw from the study. Information will be collected using pre-tested, pre-designed questionnaire and the device measurement will be recorded.

Withdrawal from participation in the study: Participation in this study is voluntary. You will be free to decide whether to participate in this study or continue participation once enrolled. In case you decide to withdraw your participation, you are free to do so. However, please convey the decision to the principal investigator.

Possible benefits from participating in the study: You will not get any benefits by participating in this study. The data gathered will help population at large.

Possible risks from participating in the study: There are no risks involved in participating in this study.

Privacy and confidentiality: The information collected from you will be coded, to prevent any person to identify you. Your identity will never be revealed. The data collected from you will be kept confidential and only processed or aggregated data will be used for publication.

Financial incentives: You will not receive any payment for participating in this study.

Authorization for publication of aggregated data: Results obtained after processing of the aggregated data will be published for scientific purpose and or presented to scientific groups. However, your identity will never be revealed.

Legal rights: By signing this consent form, we are not waving any of your legal rights.

CONSENT STATEMENT

I am making a voluntary decision to participate in the study, MATERNAL EXPOSURE TO INDOOR AIR POLLUTION AND BIRTH OUTCOMES - A LONGITUDINAL STUDY.

My signature below indicates that I have decided to participate and I have read the information provided above or the information provided above has been read to me in the language that I understand best. I was given the opportunity to ask questions and that they have been answered to my satisfaction.

Name of the participant:

Signature or left thumb impression of the participant:

Name of the witness:

Signature or left thumb impression of the witness:

Name of the investigator:

Signature of the investigator:

ANNEXURE - II

QUESTIONNAIRE

“Maternal exposure to indoor air pollution and birth outcomes

- a longitudinal study.”

Sl. No: _____

Date of registration: _____

I. Sociodemographic details:

1. Name:
2. Age: Years
3. Religion: Hindu / Muslim / Christian
4. Education: Illiterate / Primary / Secondary / PUC / Graduate
5. Occupation: Unemployed / Employed (Factory / Office / Manual / Agriculture / Others)
6. Marital status: Married / Unmarried / Widow
7. Education of husband: Illiterate / Primary / Secondary / PUC / Graduate
8. Occupation of husband: Unemployed / Employed (Factory / Office / Daily wager / Agriculture / Others)
9. Type of family: Nuclear / Joint
10. Number of family members: 1 / 2 / 3 / 4 / 5 / >5
11. Total income of the family:
12. Per-capita income: Rs. /- month
13. Socio-economic status: 1 / 2 / 3 / 4 / 5

II. Obstetric history:

1. Age at marriage:

2. Married life in years:
3. Obstetric score: G P A L
4. Duration of pregnancy: weeks
5. Expected date of delivery:
6. Any previous history of Preterm / Intrauterine death / Still birth / Low birth weight

III. Past history:

1. Past history: Diabetes / Hypertension / Asthma / Chronic ronchitis / Tuberculosis / Heart disease
2. Health status

Sl. No.	Disease / Symptom	Experienced the disease / symptoms	Frequency of episodes per year	Duration	Received treatment	Was hospitalization required any time?
1	Diminished vision / Watering or irritation of eyes	Yes / No			Yes / No	Yes / No
2	Throat irritation / Ear pain / Chronic bronchitis / Asthma / Cough with sputum or without sputum / Rhinitis	Yes / No			Yes / No	Yes / No
3	Skin Burns / Blisters / Skin irritation	Yes / No			Yes / No	Yes / No
4	Others	Yes / No			Yes / No	Yes / No

3. Habits if any

Habits	Duration and frequency per week	If left, since how long
Beedi/cigarette smoking		
Alcohol		
Chewing tobacco		
Others (specify)		

IV. Housing characteristics

1. Type of house: Kucha / Pucca / Semi-Pucca
2. Floor material: Mud / cement / Clay
3. Wall material: Mud / stone / Brick
4. Roof material: Thatch / Asbestos / Tiles
5. Dampness: Present / Absent
6. Number of rooms: 1 / 2 / 3 / 4 / 5
7. Overcrowding: Present / Absent
8. Source of lighting: Electric / Biogas / Lantern
9. Ventilation of the house: Adequate / Inadequate
10. Cattle shed inside the house: Present / Absent
11. Any domestic animals inside the house: Present / Absent

V. Kitchen / cooking area characteristics

1. Windows in kitchen: Present / Absent
2. Windows open while cooking: Yes / No
3. Door in kitchen: Present / Absent
4. Doors open while cooking: Yes / No
5. Cross ventilation: Present / Absent

6. Smoke outlet / Exhaust fan in the kitchen: Present / Absent
7. Presence of soot on the kitchen wall: Present / Absent
8. Lighting of the kitchen: Adequate / Inadequate

VI. Cooking practices:

A. Cooking status:

1. Started cooking at age: years
2. Number of years you have been cooking:
3. Involved in cooking at present: Yes / No
4. If not, in past have been involved incooking: Yes / No
5. Exposed to cooking fuel use but never involved in cooking: Yes / No
6. Where do you cook usually?
 - a) In a room used for living or sleeping (with partition)
 - b) In a room used for living or sleeping (without partition)
 - c) In a separate room used as kitchen
 - d) In a separate building used as kitchen
 - e) Outdoors

B. Type of fuel used:

Purpose	Fuel used*		Duration of usage in years		Average use in hours		Reason for using fuel**	
	Fuel 1	Fuel 2	Fuel 1	Fuel 2	Fuel 1	Fuel 2	Fuel 1	Fuel 2
Cooking for home								
Heating water								
Cooking animal feed								

*- Solid fuel: Wood / Charcoal / Crop residue / Animal dung

Non solid fuel: Kerosene / Liquefied petrol gas / Biogas / Electricity

**_

- a) More affordable
- b) Easily available
- c) The fuel is of better quality
- d) The fuel produces less smoke
- e) Takes lesser time to cook
- f) Others _____

C. Type of stove used for cooking: Chula / Kerosene Stove / LPG stove / Others if any

D. How long does it take to cook one meal?

- a) Breakfast- _____ mins
- b) Lunch- _____ mins
- c) Dinner- _____ mins
- d) Others (Specify)- _____ mins

E. Use kerosene lamps: Yes / No

- If yes number of years using kerosene lamps?

F. After use of biomass, method of disposal used:

- a) Dumping
- b) Burning
- c) Composting
- d) Burial

VII. Habits in the household members

1. Does anyone smoke in your household? Yes / No

If Yes

Sl. No.	Household member	Number of cigarettes / bidis day	Duration (Years)
1.			
2.			
3.			

2. Where do you and / or other family members (if any) primarily smoke?

- a) Inside the house
- b) Outside the house
- c) Both inside and outside the house

3. Do you burn incense sticks in your house? Yes / No

4. How many incense sticks do you burn per day? _____

5. Do you burn mosquito coils in your house? Yes / No

6. How many mosquito coils do you burn per day? _____

VIII. General Physical Examination

1. Height: _____ cm

2. Weight: _____ Kg

3. BMI: _____ kg / m²

IX. Measurements:

1. Hb:

2. PM_{2.5}: _____ µg/m³

X. Outcomes:

1. Mode of delivery: Normal vaginal delivery/ Lower segment caesarean section /

Forceps delivery

2. Birth outcomes:

- Full term
- Preterm
- Normal birth weight: Birth weight: _____kg
- Low birth weight: Birth weight: _____kg
- Abortion
- Still birth