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# An analysis of Indoor air quality of improved biomass Cookstove: A way to reduce health hazards of kitchen worker

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**Abstract**
Biomass is still used in most of the developing countries for cooking in rural household as well as for community. Traditional cookstove emit greenhouse gases like CO and $CO_2$ and other pollutants like PM (2.5) because of its poor thermal and combustion efficiency. These pollutants directly affect people's health who works with the cookstove or have direct contact with these gaseous pollutants. The study deals with the improved cookstove to assess the Indoor air quality by taking measurements of different parameters like CO, $CO_2$ and Total Particulate Matter (PM2.5) using relevant instrument such as Indoor air quality monitor. During experimentation of WBT, thermal efficiency and the average power output rating of improved cookstove with *Prosopis juliflora* was founded as 34.45% and 1.46 kW, respectively. The average CO, $CO_2$ and Total Particulate Matter (PM2.5) produced during WBT was resulted as 19.06 ppm, 878.69 ppm and 3.04 mg $m^{-3}$, respectively. Use of improved cookstove saves energy and also helpful in reducing pollutant emission which automatically leads to mitigating greenhouse gases. Thus, the government and policymaker should take step to advertise and implement such a cooking system in needy areas which helpful in reducing the amount of fuelwood used and also preserve our environment.

**Keywords:** Improved cookstove, indoor air quality, particulate matter, water boiling test, pollution, Green House gas

## 1. Introduction

India is a vast country, with diverse food, various climatic zones, different culture or tradition, different style of cooking and different environmental condition with a huge population. India has approximately about 7 Million restaurants in organized category and more than 23 Million restaurants, *dhaba's, thela's* etc. in unorganized sector (Apex body of Indian hospitality industry, Times of India, 2020). Workplaces like these having a large number of workforce and the workers were facing various problems like heat stress, heat stroke, uncomfortable environment, pollution and various health hazards for longer duration (Kshirsagar, 2013) [8].

Worldwide, around 2.4 billion people still cook using solid fuels (such as wood, crop waste, charcoal, coal and dung) and kerosene in open fires and inefficient stoves hence being exposed to indoor air pollution (World Bank, 2022) [2]. According to World Health Organization (2014) [3] approximately 4.3 million people die from indoor air pollutants each year. The research studies have shown that respiratory diseases, such as asthma, abnormal lung function, and increased lung cancer and mortality among hotel and restaurant/cafe staff, are associated with exposure to pollutants (Arya, 2020) [4]. The majority of households in developing countries depends on solid fuels for their primary cooking energy and exposure to pollutants from combusting these fuels are estimated to be responsible for four million premature deaths per year. Unsustainable use of wood and charcoal can also lead to deforestation and ecological degradation. There are a variety of promising technologies and fuels with strong fuel and emissions performance that can address the health and environment challenges of using solid fuels (Kankaria, 2014) [7]. The morbidities associated with indoor air pollution are respiratory illnesses, *viz*., acute respiratory tract infection and COPD, poor prenatal outcomes like low birth weight and still birth, cancer of nasopharynx, larynx, lung, and leukemia etc. (Torres, 2021) [11]. A study reported that reduction in wood smoke exposure by use of improved chimney stove resulted in lowering the adverse health effect.

Traditional Cook Stove is a 3-stone stove that uses more biomass in cooking due inefficient technology. Due to its inefficiency a lot of firewood is used and a lot of smoke is produced which is harmful for health and environment.

The use of traditional cook stoves has led to increased rates of forest degradation especially in rural areas (Emukule, 2021) [5]. High temperature and humidity levels can also increase concentrations of some pollutants (Mukkannawar, 2014) [9]. As a result of the traditional cook stoves being a danger to human health and the environment, (Kalita, 2019) [6], improved cook stoves especially in the rural areas where the majority of the population depends on traditional biomass (wood, charcoal, dung etc.) can be used as a preventive measure (Raman, 2013) [10].

**Fig 1:** Experimental set up testing IAQ

## 2. Materials and Methods

An experimental investigation was conducted by organizing the Water Boiling Test on the Cookstove designed by the Renewable Energy Engineering department of College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan. Indoor Air Quality, Relative Humidity, noise level, Air Temperature and Dew Point was measured by using IAQ Monitor, Hygrometer, Sound Monitor, Fluke Thermographic Camera respectively. Frequency, Percentage, Average and Karl Pearson Correlation Coefficient test were used for the analysis of data statistically. The emission measurements were taken during and after the experiment using Indoor Air Quality measuring device called as IAQ Monitor. During the period of experimentation, firstly we setup the IAQ Monitor in the kitchen and then we collect the data for the analysis in the interval of five minutes. The main aim of examining the CO, $CO_2$ and PM2.5 emission was to check the pollution level that occur during cooking process.

## 3. Instrumentations and measurements

**Table 1:** Instruments used for the study

| S. No. | Instrument | Model | Measurement |
|---|---|---|---|
| 1. | Indoor Air Quality Monitor | Gas Probe IAQ | Carbon Monoxide |
| 2. | Indoor Air Quality Monitor | TSI Quest EVM-7 | $CO_2$ and PM2.5 |

## 4. Result and Discussion

### 4.1 Carbon Monoxide Concentration

The Carbon Monoxide emission from designed cook-stove was recorded with the help of IAQ Monitor during WBT. The CO emission was taken in every five minute time interval for the test and the emission trend with respect to time (during and after WBT) is shown in fig. 2 and 3 respectively. It can be seen from graphical representation that the average CO emission for Test I, Test II and Test III with *Prosopis juliflora* was found 9.5 ppm, 19.36 ppm and 17 ppm, respectively. During the experimentation the average CO emission for Test I, Test II and Test III examined as 10.36 ppm, 24.92 ppm and 21.91 ppm and after the experiment it was calculated as 6.83 ppm, 13.82 ppm and 12.1 ppm respectively. It can be clearly seen from these data that the CO concentration is gradually decreases after the WBT was completed.

It is clearly observed from the study that the CO emission was increasing at rapid rate in all tests from the starting of ignition to some extent and then the emission started declining till the end. The maximum and minimum CO emission were found from the Test I during the experimentation was 32 ppm and 2 ppm and after the test it was noted as 14 ppm and 2 ppm respectively. From the Test II maximum and minimum CO emission was 60 ppm and 3 ppm during the study and 20 ppm and 3 ppm after the experiment. According to the third test maximum and minimum CO emission was 31 ppm and 4 ppm during the experiment and 24 ppm and 2 ppm after the experiment.

In the second test the CO emission went to its peak (60 ppm) because at that point the researcher put a large amount of fuel at a time. Due to this, the flame decreased gradually and smoke generation increased rapidly. Because the quantity of smoke generation was more and the cross sectional area of both chimneys were comparatively small for the passage of large amount of smoke generated at a time, so for that reason CO concentration was highest at that point.

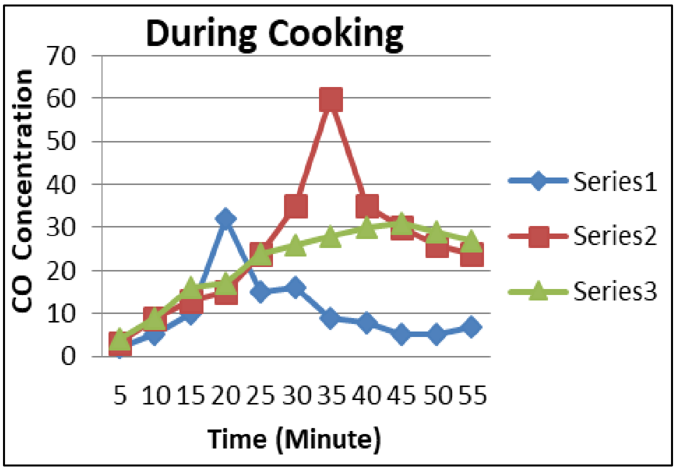


**Fig 2:** Emission of carbon monoxide concentration during cooking

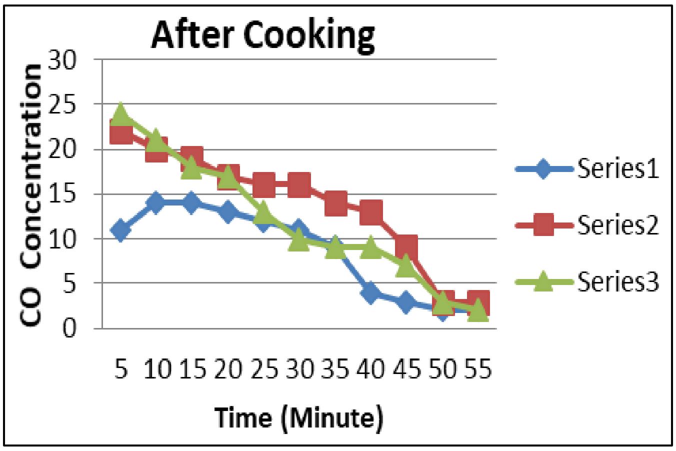


**Fig 3:** Emission of carbon monoxide concentration after cooking

### 4.2 Carbon Dioxide Concentration

The $CO_2$ emission from designed power cook-stove was recorded with the help of Indoor Air Quality Monitor during

WBT. The graphical representation of emission trend with respect to time is presented in the fig 4. and 5 respectively. The $CO_2$ emission was taken in every five minute time interval for the test, during and after the study. The average $CO_2$ emission for Test I, Test II and Test III was found 609.68 ppm, 819.1 ppm and 609.27 ppm, respectively. During the experimentation the average $CO_2$ emission for Test I, Test II and Test III examined as 811.36 ppm, 1176.27 ppm and 648.45 ppm and after the experiment it was tabulated as 408 ppm, 461.91 ppm and 570.09 ppm respectively. It can be clearly seen from these data that the $CO_2$ concentration is randomly decreases after the WBT was completed.

Fig. depicted that the $CO_2$ emission was increasing at rapid rate in all tests from the starting of ignition to some extent and then the emission started declining till the end. The maximum and minimum value of $CO_2$ emission was found from the Test I during the experimentation were 32 ppm and 2 ppm and after the test it was noted as 14 ppm and 2 ppm respectively. Test II shows the maximum and minimum amount of $CO_2$ emission were 60 ppm and 3 ppm during the study and 20 ppm and 3 ppm after the experiment. As per the third test maximum and minimum value of $CO_2$ emission was 31 ppm and 4 ppm during the experiment and 24ppm and 2 ppm after the experiment.

As seen in the Fig. 4, in the second test the $CO_2$ emission went to its peak (1633 ppm) because at that point the researcher put a large amount of fuel at a time. Because of this, the flame decreased gradually and smoke increases rapidly. Because the quantity of smoke generation was more and the cross sectional area of both chimneys was comparatively small for the passage of large amount of smoke generated at a time, so for that reason $CO_2$ concentration was highest at that point. At the time of feeding after the interval of every five minutes emission of $CO_2$ was high due to the combustion of fresh fuel fed. The higher $CO_2$ emission reveals the complete combustion of fuel that used during WBT. Therefore, it is clear that the *Prosopis juliflora* was burning consequently with minimum residues.

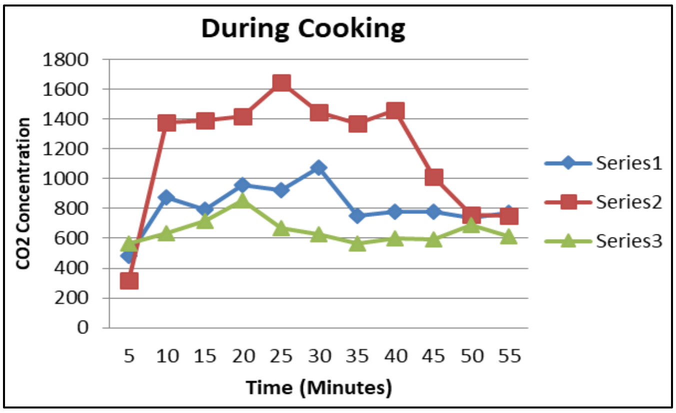


**Fig 4:** Emission of Carbon Dioxide Concentration during Cooking

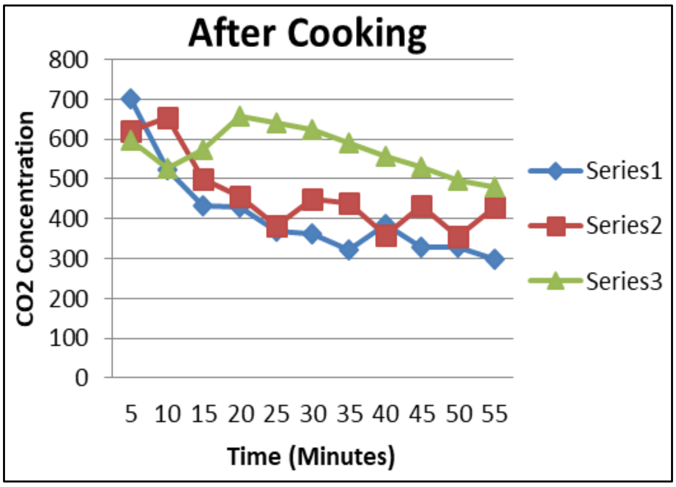


**Fig 5:** Emission of Carbon Dioxide Concentration after Cooking

### 4.3 Particulate Matter (PM 2.5) Concentration

PM 2.5 emission recorded with the help of IAQ Monitor and the emission trend, during and after the study is shown in Figure 6 and 7 respectively. The PM 2.5 emission were taken in every five minute time interval for the test. It can be seen from fig. that the average PM 2.5 emission for Test I, Test II and Test III was found 1.47 mg/m3, 2.4 mg/m3 and 0.86 mg/m3, respectively. During the experimentation the average PM 2.5 emission for Test I, Test II and Test III examined as 2.82 mg/m3, 4.72 mg/m3 and 1.58 mg/m3 and after the experiment it was calculated as 0.11 mg/m3, 0.08 mg/m3 and 0.14 mg/m3 respectively. It can be clearly seen from these data that the PM 2.5 concentration is gradually decreases after the WBT was conducted.

As seen in the figures the PM 2.5 concentration were increasing at rapid rate in all tests from the starting of ignition to some extent and then the emission started declining till the end. The maximum and minimum PM 2.5 emission was found from the Test I during the experimentation were 32 mg/m3 and 2 mg/m3 and after the test it was noted as 14 mg/m3 and 2 mg/m3 respectively. From the Test II maximum and minimum PM 2.5 emission was 60 mg/m3 and 3 mg/m3 during the study and 20 mg/m3 and 3 mg/m3 after the experiment. According to the third test maximum and minimum PM 2.5 emission was 31 mg/m3 and 4 mg/m3 during the experiment and 24 mg/m3 and 2 mg/m3 after the experiment.

In the second test the PM 2.5 emission went to its peak (13.41 mg/m3) because at that point the researcher put a large amount of fuel at a time. Due to this, the flame decreased gradually and smoke generation increased rapidly. Because the quantity of smoke generation were more and the cross sectional area of both chimneys were comparatively small for the passage of large amount of smoke generated at a time, so for that reason PM 2.5 concentration was highest at that point.

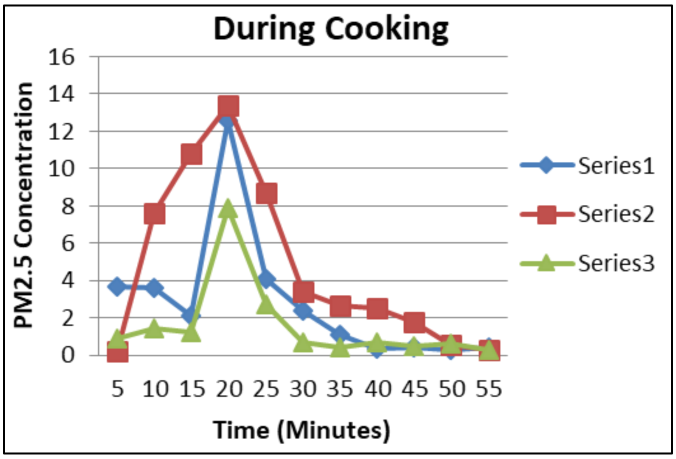


**Fig 6:** Emission of PM 2.5 Concentration during Cooking

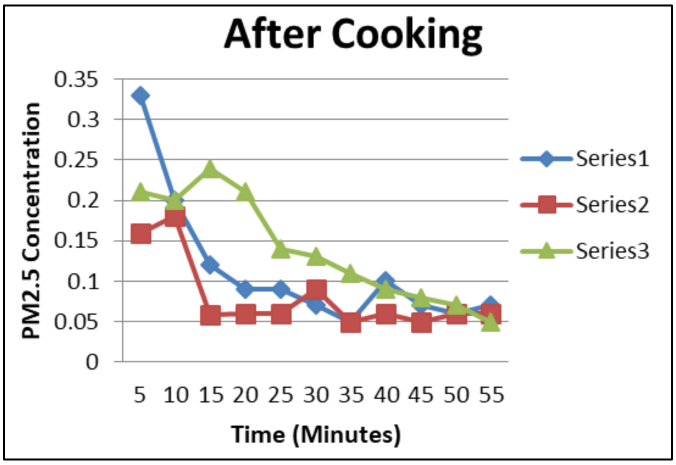


**Fig 7:** Emission of PM 2.5 Concentration after Cooking

## 5. Conclusion

When the improved cookstove was compared with other previously examined cookstove, it can be clearly seen that the newly developed cookstove is more thermally efficient. The developed cookstove is enabled to save valuable amount of fuel used and produces lesser MRT. It was found that the developed cookstove is working efficiently and saving considerable amount of CO, $CO_2$ and PM (2.5) emission. Working in this cookstove create more thermally comfortable working environment than the traditional one. Because it has three-pot for cooking, it saves both time and energy in comparison to the other cookstoves. The rural and needy people can easily afford the developed cookstove. The purchasing cost spent for cookstove can also easily be recovered because the cookstove was made only from bricks and cement.

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