A Study of Indoor Carbonaceous Aerosols and the Socio-Economic Parameters in a Rural Area of Himachal Pradesh, India

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Abstract.
Solid Biomass Fuel (SBF) burning is one of major reasons for the indoor air pollution and high disease burden in rural areas of India. This study has made an effort to find out the association of carbonaceous aerosol (CA) emissions with the socio-economic factors in the households of a rural village, Baggi in Himachal Pradesh, India. Also, the emissions of Organic Carbon (OC) and Elemental Carbon (EC) were evaluated for different types and combination of fuel combustion for cooking and heating purposes. Enhanced average concentrations of OC (240 µg/m³) and EC (118.4 µg/m³) were found with sole biomass burning (wood) on the Chullah (traditional low-budget cookstoves) due to inefficient and incomplete combustion. Although, there was a significant reduction of 53% and 41% in OC and EC respectively when a combination of biomass and Liquefied Petroleum Gas (LPG) was used for cooking. With LPG, the concentrations of OC and EC significantly declined to as low as 38.1 µg/m³ and 31.6 µg/m³ respectively. Also, an excellent inter-relationship was identified between the socio-economic parameters such as the kitchen’s ventilation, education, financial status, etc. and CA emissions. In the house with very good ventilation (2 wide windows), the total CA emissions were as low as 86.7µg/m³. Also, the family members were educated and financially affluent. On the other hand, the total CA emissions were escalated by a significant 75.9% where the ventilation facility was extremely poor (small window and slit in the roof), the family was limitedly educated, and financial status lied below poverty line. On an average, the women in this village were found to spend 5 hours per day in the kitchen area. The socio-economic parameters are necessarily important towards the mitigation indoor air pollution and hence carbonaceous aerosols.

Keyword: Organic Carbon, Elemental Carbon, Solid Biomass Fuel
1. Introduction
India is a rural major developing country, and majority of the rural population is dependent on burning solid biomass fuel for cooking and heating. Figure 2 is a clear depiction of population using different types of fuel for cooking. A large fraction of population is dependent on burning biomass viz. firewood, crop residue, cow dung cake, etc. This study has focused on the carbonaceous emissions of hilly areas. The hilly areas of India have a major role to play in determining country’s climatic conditions, by controlling or providing protection from various factors such as dust storms, wind, etc. The residents in hilly areas are compelled to use biomass for cooking and heating purposes as facilities of Liquefied Petroleum Gas (LPG) are difficult to avail regularly because of tough terrain, which then results in increase in carbonaceous aerosols in the immediate indoor environment.

2. Material and methods
This study focuses on studying carbonaceous aerosol concentration in selected houses of Baggi, a very small village in Hamirpur district, Himachal Pradesh (figure 1). This study is carried out in four houses which were asked to use different set of fuels for cooking. The indoor carbonaceous concentrations of these households were evaluated during morning, afternoon and evening times when usually the residents used to cook. The aerosol samples were collected on 42mm Quartz fibre filters mounted on filter holder connected to the suction pump for 3 hours. The traditional cook stove used is called Chullah and the fuel used is cow dung cake or wood.

![Figure 1. India and the sampling site: Baggi, Himachal Pradesh](image)

3. Results and discussions
The variation of Organic Carbon(OC), Elemental Carbon (EC) and hence Total Carbon (TC) throughout the sampling period in figure 2 is suggesting that their concentrations peaks when biomass burning takes place, lowers down a bit when LPG is used along with biomass burning and forms a node of almost negligible concentration during non-cooking times.

The residents were then advised to use different combination of fuels (figure 3). When biomass was burnt for cooking in Chullah the carbonaceous aerosol concentrations were the highest (OC=240µg/m$^3$; EC=118µg/m$^3$). When they were advised to cook partial meal on Chullah and partial meal on LPG, there was a considerable decrease in the concentrations (OC=112 µg/m$^3$; EC=68 µg/m$^3$). Although, there was a significant reduction of 84% in OC and 73% in EC concentrations when the residents cooked entire meal on LPG.

As shown in figure 4, there was an excellent correlation between OC and EC concentrations, with $R^2$ =0.93 which proves that OC and EC are coming from the same source.
Figure 2. Variation of OC, EC and TC throughout the sampling period

Figure 3. Comparison of OC, EC & TC in Different Fuel Combinations
4. Conclusions

This study concluded that the burning of biomass for cooking results into alarmingly high levels of carbonaceous aerosols in the indoor environment. Rural population is not well versed with the harmful effects of indoor air pollution on health which is being caused by Chullah’s smoke containing unburnt carbon (black carbon) and hence there is a dire need of bringing awareness to them. Because of the financial constraints, limited reach of government facilities and their conventional thought pattern, people here are compelled to continue with the traditional practices of cooking on Chullah. In spite of changing the overall techniques of cooking, which is not cost-effective, we can implement modest improvisations in their practices with the existing facilities which can bring significant reduction in carbonaceous aerosol emissions. This approach is called soft approach as is being done in this study.

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