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Indoor Air Pollution from Household Cooking and Associated Health Hazards of Selected Rural Communities of Madhupur Tract in Bangladesh

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Abstract: Indoor air pollution is deemed one of the most severe environmental pollutions that occur mainly due to the inefficient and incomplete combustion of solid cooking fuels, which emits different types of particulate matter ($PM_{2.5}$, PM_{10}). Therefore, this study was organized in the hilly rural area of Sagordighi of Tangail district in Bangladesh to monitor the atmospheric particulate matters $PM_{2.5}$, PM_{10} and CO (carbon monoxide) concentrations from the rural kitchens as well as the possible health hazards due to exposure of the air pollutants. One hundred and thirty air samples were collected from the kitchens by using Airveda air quality monitor and Testo 317-3 - Ambient CO meter to monitor the particulate matter and carbon-monoxide concentrations respectively during cooking and non-cooking time. A survey was also conducted through questionnaire. The concentrations of $PM_{2.5}$ fluctuated from 112-999 μgm^{-3} whereas the mean concentration was 401.88±232 μgm^{-3} during cooking time. On the other hand, PM_{10} concentration varied from 114-1999 μgm^{-3} were observed during cooking time with a mean concentration was 523.10±413 μgm^{-3}. The concentration of $PM_{2.5}$ varied from 32-362 μgm^{-3} at non-cooking period while the mean value was 81.38±41 μgm^{-3}. The concentration of PM_{10} ranged between 55-429 μgm^{-3} at non-cooking period and the mean of PM_{10} was 109.51±51 μgm^{-3}. The mean concentration of CO during cooking period was 51.52±17 ppm and it varied from 20 ppm to 96.4 ppm. On the contrary, the mean concentration of CO during non-cooking period was 6.60± 6 ppm and it fluctuated from 0 to 40 ppm. The concentration of atmospheric particulate matter showed the highest concentration during cooking time. Contemplation on the measured concentration of particulate matters, these values were greater than concentration found in many European cities and also surpassed the Bangladesh National Ambient Air Quality Standard. The monitored CO value exceeded the recommended value. Questionnaire survey result indicated that respondents suffered from various diseases due to household cooking activities such as facing eye irritation, headaches, dry cough, dizziness and nasal congestion during cooking time. This research suggests installation of improved cooking stoves and providing proper ventilation facilities in kitchen and using renewable energy as well as creating public awareness among rural communities for minimizing the impacts of pollutants emitted from cooking activities.

Keywords: Indoor air quality; Cooking fuel; Particulate matter; Health Hazard; Rural community.

INTRODUCTION

Air pollution is the common health problem all over the world. Although many people are concern about outdoor air pollution that can negatively impact on human health, but most are unaware about the harmfulness of indoor air pollution. Indoor air pollution coming from combustion of traditional biomass fuels such as wood, cow dung, leaves, twigs and agricultural residues such as straw and husk. These fuels have been collected locally and used for cooking purposes and responsible for health problems especially in the rural communities.

Women especially who are responsible for cooking using traditional stoves are more vulnerable to health hazard causing from air pollution (Begum et al.2009; Sun et al. 2017).

It is very important for causing human health hazards due to the inhalation of different pollutants and its exposure intensity depends on the size of the pollutants because particle-bound pollutants are size-dependent (Zhao et al. 2022).

There is an increasing concern about atmospheric particulate matter (PM) that creates different types of health hazards and it depends on the size distribution of atmospheric particulates (Li et al. 2017a; Shen et al.2017). The PM with a diameter of 10 µm or less has the ability to enter into the deeper respiratory tract region through inhalation. On the contrary, the fine PM ($PM_{2.5}$) and finer PM ($PM_{1.0}$ and $PM_{0.25}$) can easily enter to the lung and blood circulatory system, triggering various diseases particularly respiratory diseases and asthma, (You et al. 2017). Personal health risk from $PM_{2.5}$ and the variation of the concentrations of $PM_{2.5}$ are controlled by the types of stoves, heating fuel, and presence of a chimney as well as ventilation of the kitchen (Shupler et al. 2022). So, it is very important to know the factors effecting on the emission of particulate matters $PM_{2.5}$ such as location and configuration of the household kitchen and stoves as well as the used fuels (Muteti Fana, et al. 2023)

Indoor air pollution emitted from household fuel combustion is one of the principal causes of disease and premature death in the developing world. There are about 3.8 billion peoples in low and middle income countries who use different types of biomass fuels as their cooking activities as well as for heating (Younger et al.2022). It was reported that in 2016 about 3.8 million deaths caused by household air pollution and it is also responsible for 7.7% of the global mortality (WHO, 2016). In Bangladesh, 9 out of 10 families use biomass as fuel and traditional cook stoves for cooking. Moreover, 14000 women and 32000 children die every year due to diseases caused by kitchen smoke (VNV Advisory, 2022).

Biomass fuels contribute approximately 70% of total fuel used in cooking activities in Bangladesh (Masud et al.2019). Rural communities use the solid fuel for cooking activities and most of them are unaware about its harmful effects. Considering the mentioned health hazards, it is very important to investigate the impact of ambient air pollutants such as $PM_{2.5}$, PM_{10} and CO that produced from household cooking and also the possible suggestions to minimize the indoor air pollution in Bangladesh. Multiple studies conducted in Bangladesh concluded that such a practice is a contributor to the development of childhood pneumonia, which is considered to be the cause of one fifth of all deaths in children under the age of five (BDHS, 2014; Fullerton et al., 2008).

Several researches on air pollution at different region of Bangladesh have been performed like Dhaka, Pabna and research found significance result on air pollution. Concentration of air pollutants found in city is detrimental for human health (Begum et al., 2013). The mean values of PM were 413.02, 292.63, 671.65, 184.09 and 301.13µgm^{-3} in Dhaka, Noakhali, Chittagong, Faridpur and Kustia, respectively, which were higher than the recommended values of WHO and US EPA standard. A research work was conducted by Mondol et al. (2014) and found the highest value in Chittagong (671.65 µgm-3) whereas the lowest in Faridpur (184.09 µgm^{-3}). The concentrations of $PM_{2.5}$ at Ashuganj in Brahmanbaria ranged from 12.2–145 µgm^{-3} and the the mean value of that area was 67.09 µgm^{-3}. On the other hand, PM_{10} value fluctuated from 20.5–220 µgm^{-3} where the average value was 103.64 µgm^{-3} whereas the concentration (Baitun et al., 2018).

Therefore, cooking has been recognized as main sources of PM pollution especially in developing countries like Bangladesh but researches are restricted to cooking style of selected locations.

Moreover, according to knowledge, research has not been published yet concerning air pollution of Tangail city. Therefore, this research was conducted on emission of air pollutants from cooking activities in hilly rural area a) to determine the concentrations of air pollutants ($PM_{2.5}$, PM_{10} and CO) due to household cooking activities in rural areas and b) to assess the probable health hazard due to exposure of air pollutants**.**

MATERIALS AND METHODS

Study Area and Sampling

Sagordighi is a union under Ghatail upazila in Tangail District. It is the 27 km distance from the upazila sadar of Ghatail that is belongs to the eastern part of Modhupur tracts (Wikipedia 2021). This area is located within sal forest and enriched with various kinds of vegetations. Four villages (Guptabrindabon, Gandinapara, Taltala and Suaitpur) were selected from the Sagordighi union in Ghatail Upazila (Figure 1).

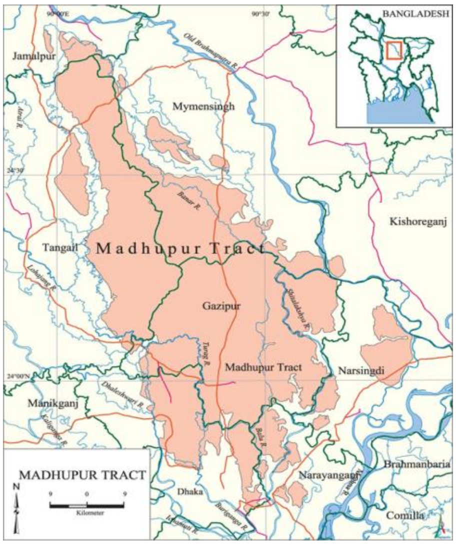

Figure 1. Sampling location at Sagordighi Union in Ghatail Upazila of Tangail district

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Therefore, people living in this area use biomass as cooking fuel. As Sagordighi is the large village the households were selected in randomly on the basis of the objectives of the study. Total 65 households were selected from rural areas of Tangail districts for real-time measurement of $PM_{2.5}$, PM_{10}, and carbon monoxide. Total 130 samples were collected (cooking time: 65 samples and non-cooking time: 65 samples) from the study areas. Samples were collected during cooking and non-cooking periods from the selected households.

Sampling period and instrumentation

Data were collected during September and October from 7.00 AM to 10.00 AM and between 12.00 PM to 4.00 PM. Particulate Matter ($PM_{2.5}$, PM_{10}) data were collected using Airveda particulate matter monitor (Model: PM2510CTH) whereas Testo 317-3 ambient CO meter was used to collect CO data from the households. Scale of the Airveda Air Quality Monitor has been given in Table 1.

Table 1. Scales of Airveda Air quality monitor

Air Quality Parameter	$PM_{2.5}$ (µgm-3)	PM_{10} (µgm-3)
Severe	250	430
Very poor	120	350
Poor	90	250
Moderate	60	100
Satisfactory	30	50
Good	0	0

Health Risk Assessment

A questionnaire was prepared for collecting the information of the respondents in respect of purpose of the study. The questionnaire was divided into several parts such socioeconomic status of the respondents, cooking activities, kitchen & cooking stoves design and kitchen ambient air pollution and health complication of the respondents. Answers of the questionnaire in most of cases are open and sometimes are closed form. The concentration data were noted in the questionnaire. At the same time, the respondents were asked different questions followed by the structured questionnaire after seeking kitchen and other facilities of the household. The respondents were asked and noted the answer of the respondents by questionnaire sitting on the household premises with the congenial atmosphere.

RESULTS AND DISCUSSION

Fine Particulate Matter ($PM_{2.5}$)

The concentration of $PM_{2.5}$ during cooking ranged between 112 µgm^{-3} to 999 µgm^{-3} having a mean of 401.88±232 [mean ± standard deviation (SD)] (Figure 2). Based on the scale of Airveda monitor, this mean value indicated that the condition of air quality inside the kitchen is severe. The concentration was much higher than the limit set by Bangladesh Government (65 µgm^{-3}). The mean value of $PM_{2.5}$ (81.38±41 µgm^{-3}) during non-cooking was also higher than the recommended limit. The highest concentration was 362 µgm^{-3} where minimum was 32 µgm^{-3}. This is may be due to the collection of samples within 1-2 hrs after cooking. However, the concentration was 126.5 µgm^{-3} for the cooking fuel charcoal (Muindi et al., 2016). The concentration of $PM_{2.5}$ was 166 µgm^{-3} in the air of Match Colony slum, Shyampur whereas the concentration was 117 µgm^{-3} in the air of City Polli Slum, Dholpur (The Business Standard, 2022).

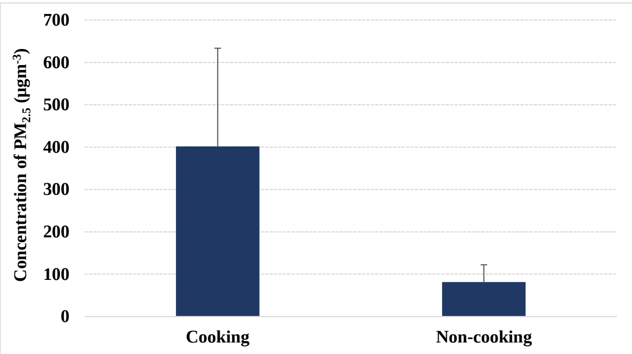

Figure 2. Concentration of fine particulate matter ($PM_{2.5}$)

Coarse Particulate Matter (PM_{10})

Considering all the data, the concentration of PM_{10} during cooking fluctuated from 114 µgm^{-3} to 1999 µgm^{-3} whereas the average value was 523.1±413 [mean ± standard deviation (SD)] (Figure 3). On the other hand, the concentration of PM_{10} ranged 55 µgm^{-3} to 429 µgm^{-3} during non-cooking period. The mean value of PM_{10} (109.51 ± 51 µgm^{-3}) at non-cooking period is also higher than the recommended limit set by the Government of Bangladesh. This is may be due to the collection of samples within 1-2 hrs after cooking. Rabha et al. (2018) conducted a study on cooking fuel users in Assam and found higher concentration of $PM_{2.5}$ and PM_{10} from wood users compared to LPG users. The $PM_{2.5}$ and PM_{10} values were 644.4± 368.3 µgm^{-3} vs 50 ± 23.8 µgm^{-3} and 915 ± 441.3 µgm^{-3} vs 83.3 ± 33 µgm^{-3} for wood and LPG users, respectively. Dasgupta et al. (2006) measured PM_{10} concentration of biomass fuel from 600 household covering six regions of Bangladesh and found the highest PM_{10} concentration from dung (291 µgm^{-3}), followed by firewood (263 µgm^{-3}), sawdust (237 µgm^{-3}), straw (197 µgm^{-3}), jute (190 µgm^{-3}) and twigs and branches (173 µgm^{-3}). The differences between the study results with the

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others, it can be explained due to various attributes such as fuel type, kitchen design, ventilation facilities, geographical position and time of data collection and sometimes the per capita income (Dasgupta et al. 2006). The PM values were 77% and 41% higher in winter season compared to the values found in monsoon and summer season, respectively (Deepthi et al. 2019).

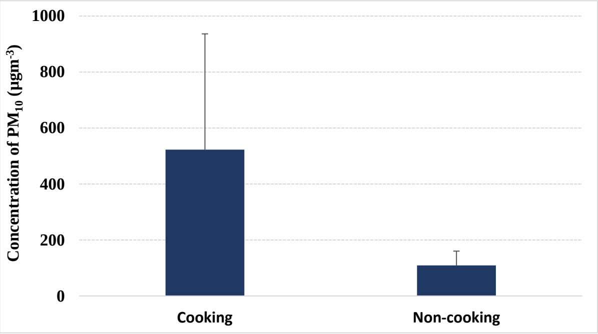

Figure 3. Concentration of coarse particulate matter (PM_{10})

Carbon monoxide (CO)

The mean concentration of CO during cooking period was 51.52 ± 17 ppm and it varied from 20 ppm to 96.4 ppm whereas the measured average value of CO during non-cooking was 6.60± 6 ppm and it ranged from 0 to 40 ppm. (Figure 4). The mean concentration of CO during cooking time was higher than the recommended value (35 ppm) of BNAAQS. The CO concentration was 6.3 ppm in rural kitchen in Uganda observed by Nakora et al. (2020) that was also lower than the results.

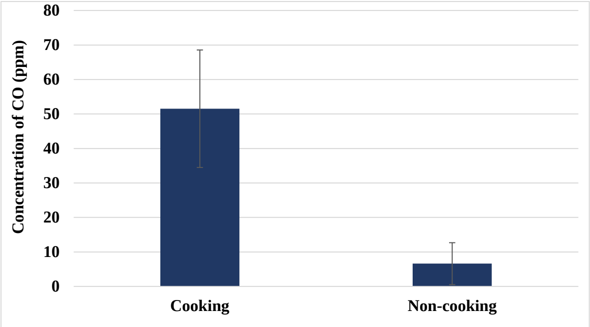

Figure 4. Concentration of CO during cooking and non-cooking period

Pollutants Emitted from Cooking Fuels

In this study, it was also investigated the concentration data of pollutants emitted from the various types of biomass fuels used by the respondents during cooking. The average maximum concentration of particulate matter, $PM_{2.5}$ was 872.00 µgm^{-3} found from the kitchens where cow-dung stick was used as fuel during cooking. The minimum average concentration (272.54 µgm^{-3}) was found from the kitchens where twigs and leaves were used as cooking fuel. The concentrations of particulate matters increase during the combustion process of the low-grade biomass fuel due to their high molecular weight hydrocarbons (Begum et al.2009). At cooking period, the mean concentrations of $PM_{2.5}$ according to fuel use in ascending order were: twig and leaves< coconut leaves < straw< wood, twig and leaves< jute stick< wood < twig< bamboo < cow-dung stick. During cooking time, the average maximum concentration of PM_{10} (960 µgm^{-3}) was found from the kitchens where cow-dung stick was used as cooking fuel. The minimum mean value (337.00 µgm^{-3}) was found from the kitchens where twigs and leaves were used as fuel. The average concentrations of PM_{10} during cooking time according to fuel use in ascending order were: twig and leaves < coconut leaves < straw <wood, twig and leaves < jute stick < wood< twig< bamboo < cow-dung stick.

The average maximum concentration of CO was recorded from the kitchens where cow-dung stick was used for cooking. The minimum average concentration was detected from the kitchens where used jute stick. During cooking the average concentrations of CO according to fuel use in ascending order were: straw<wood, twig and leaves < wood< cow-dung stick < twig< twig and leaves< bamboo < jute stick < coconut leaves. The highest concentrations of $PM_{2.5}$, and PM_{10} were recorded during cooking time where used cow-dung stick. The maximum CO concentration was found where coconut leaves were used as cooking fuel. The average value of $PM_{2.5}$ and PM_{10} were observed minimum in those kitchens where twig and leaves were used for cooking. The minimum average concentration of CO was found from straw.

Hierarchy of Cooking Fuel

The biomass solid fuel utilization is mainly dependent upon the geographical position, availability of the fuels, monthly income and social status of the household (Alam et al. 2019). In the study area, the highest number of respondents used bough (52.3%) as cooking fuel followed by wood (29.23%), leaves (29.23%), bamboo (15.38%) and straw (4.62%) (Figure 5).

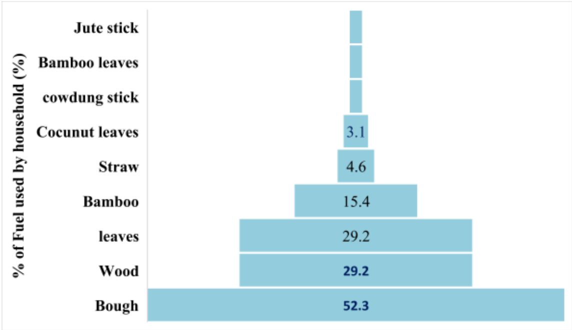

Figure 5. Hierarchy of Cooking Fuel at household level

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Health impacts faced by the respondents during cooking

It was revealed from the questionnaire survey of the study area that most of the respondents are middle aged (40%) and education levels are very low and most of them can give sign only. Besides that, most of households' yearly incomes are very low to low (72.31%) and it comes from the farming activities (55.38%). Therefore, most of the families are not able to use the clean fuels due to their socio-economic constraints. For this reason, they are compelled to use wood, crop residues, leaves and twig, cow dung sticks etc. for their cooking. In this study, based on the survey data it was noticed that 61% women faced eye irritation problem during cooking time, 30% had headaches, 27% had dry cough, 26% had asthma, 26% had dizziness, 6% had nasal congestion and 29% had no symptoms (Figure 6).

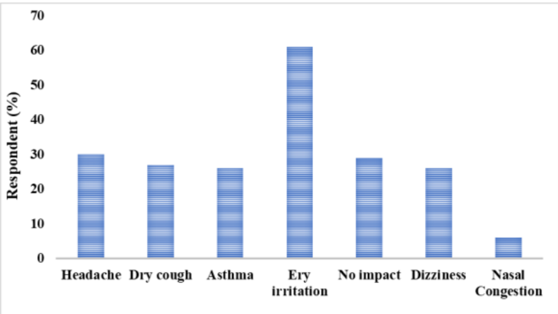

Figure 6. Health hazards during cooking of the respondents

CONCLUSION

This study represents the concentration of $PM_{2.5}$, PM_{10} and CO in rural kitchens at selected areas of Madhupur Tract. During cooking time, the concentration of $PM_{2.5}$ ranged between 112-999 μgm^{-3} whereas average value was 401.88±232 μgm^{-3}. The concentration of particulate matters ($PM_{2.5}$ & PM_{10}) showed the highest concentration during cooking time. Contemplation on the measured concentration of particulate matters, these values were greater than concentration found in many European cities and also surpassed the Bangladesh National Ambient Air Quality Standard. The mean concentration of CO during non-cooking was 6.60± 6 ppm and it varied from 0 to 40 ppm. The mean concentration of CO (51.52±17 ppm) during cooking time was higher than the standard (35 ppm) set by the Government of Bangladesh and also EU. On the basis of the measured concentration of pollutants data, we concluded that the ambient air of the selected kitchens is very unhealthy during cooking time. Besides that, it was reported from questionnaire survey that the women who engaged in cooking were facing eye irritation, headaches, dry cough, dizziness and nasal congestion during cooking time. On the contrary, the average concentrations of $PM_{2.5}$ during cooking time according to fuel use in ascending order were: twig and leaves< coconut leaves < straw< wood, twig and leaves< jute stick< wood < twig< bamboo < cow-dung stick. The highest concentrations of $PM_{2.5}$, and PM_{10} were recorded during cooking period where used cow-dung stick whereas the minimum average value of $PM_{2.5}$ and PM_{10} were detected in kitchens where twigs and leaves were used for cooking. This study revealed that the ambient air in the rural kitchen might cause health hazards to women who spend a long time of their day engaged in food preparation activities. So, initiatives have to be taken to control emissions from Kitchens. Policymakers and the local Government authority can play a vital role in building awareness and reducing indoor fine particulates such as $PM_{2.5}$, PM_{10} and CO levels in rural kitchens in Bangladesh. So, more attention should be emphasized on kitchen's structural characteristics to ensure proper ventilation by increasing numbers and wider windows in the rural kitchen as well as encourage the utilization of clean fuels for cooking activities.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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