ASSESSMENT OF INDOOR AIR QUALITY FOR COMMERCIAL COOKING SECTOR

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CANDIDATE DECLARATION

I, DUSHYANT PARASHAR, 2K16/ENE/09, student of M.Tech (ENVIRONMENT ENGINEERING), hereby declare that the project Dissertation titled "ASSESSMENT OF INDOOR AIR QUALITY FOR COMMERCIAL COOKING SECTOR" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "ASSESSMENT OF INDOOR AIR QUALITY FOR COMMERCIAL COOKING SECTOR" which is submitted by DUSHYANT PARASHAR, 2K16/ENE/09, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by him under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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DUSHYANT PARASHAR

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LIST OF ABBREVIATIONS

1. Ambient Air Pollution……………………………………………..…AAP
2. Indoor Air Pollution…………………………………………………...IAP
3. Indoor Air Quality……………………………………………………….IAQ
4. Air Quality Index………………………………………………………..AQI
5. Liquified Petroleum Gas……………………………………...……LPG
6. Global Burden of Diseases…………………………………..……GBD
7. Particulate matter………………………………………..………..PM
8. Polycyclic Aromatic Hydrocarbons…………………...…….………PAHs
9. Environmental Tobacco Smoke……………………………..………...ETS
10. Particulate Exposure……………………..……………………..….PE
11. World Health Organization……………..………………………WHO
12. Respirable Suspended Particulate Matter……………………...…RSPM
13. National Ambient Air Quality Standards………………………...NAAQS
14. Environment Air Particulate Matter…..……………………………EPAM
15. Environmental Protection Agency…………………………..………EPA

ABSTRACT

In developing countries, human exposure to ambient air pollution(AAP) and indoor air pollution(IAP) are important risk factors for morbidity and mortality. Indoor air pollution is never in limelight as these microenvironments are always considered better until an immediate effect is visualized. Out of all the known sources of indoor air pollution cooking contributes in large proportion. Bringing LPG nationwide was like boon for mankind in India. By this step we have protected women and children who are spending majority of their time indoor cooking and playing respectively. The commercial cooking sector of country where hundreds of cooks cook food all round the clock using large amount of Liquefied Petroleum Gas (LPG) like in religious places, college mess, factories, hotels, etc. They are exposed to extremely high level of concentration of pollutants and extreme temperature for long hours. Particulate matter ($PM_{2.5}$ and PM_1) most severe pollutant, associated with respiratory, cardiovascular and cerebrovascular diseases. Results of the study strongly suggest that the shift from biomass fuel to LPG has not assured safety for commercial cooking sector. In the study the concentration levels of $PM_{2.5}$ and PM_1 were found to exceed 6 to 7 times more than that of the standards set under National Ambient Air Quality Standards, that to are for ambient air quality. Apart from Natural Ventilation, exhausts and chimneys were found to reduce the PM levels significantly. Mandatory use of Green Electricity (i.e. generated through solar energy) as the substitute of LPG in commercial cooking sector is recommended. This will not only reduce the import burden on country for LPG but will also reduce the concentration levels of PM in kitchen area as all electric equipment are covered. Also, there is an urgent requirement of establishing the standards for indoor air quality including PM_1 in it.

CHAPTER 1

INTRODUCTION

Air pollution is a global environment burden and has been identified as significant public health risk. Last year the WHO assessed 1,622 cities worldwide for $PM_{2.5}$ and found India alone to have 13 of the 20 cities with the most polluted air. Air pollution can be defined as the emission of harmful substances to the atmosphere. Under this definition of air pollution, comes many pollutants like oxides of Sulphur (SO_2), oxides of nitrogen (NO_x), Ozone (O_3), Particulate matter, oxides of carbon (CO) and Volatile Organic Compounds (VOCs).

Air pollution will cause more deaths as Indians grow in age and plump. People are exposed to ambient air pollution (AAP) and Indoor air pollution (IAP). These are critical factors for illness and death. This is common in the countries those in developing phase. Indoor and outdoor pollution combinedly is reported as biggest current cause of deaths in India, taking about 1.6 million lives a year. Number of death caused by air pollution in India between 1990 and 2015 increased drastically. The issue of air pollution in India is multi-layered and miscellaneous. Handling air pollution problem in India is not just a case of Government-made policies that involves giving awards and punishments for businesses and individuals when concern for environment is shown.

Developing countries were found to be in race, keeping aside the concern for environment. This has led to the present situation when many development plans have to be discarded. If these plans are continued the mankind will be in danger now. It’s not only related to new development plans but the already running conventional practices in many areas in developing countries are responsible for major contribution. Most of the developed countries have switched on to the green technologies. Every running sector gives its contribution to the air pollution. Transportation sector, industrial sector, agriculture sector, etc are among the top contributors for an AAP. Recently many significant advancements in monitoring of ambient air pollution has come up in India. All over the world lot of efforts are put to find out the sources of outdoor air pollution and measures to reduce it. The attention must be given to the fact that more significant in amount and more serious to health are the effects of indoor air pollution.

Indoor air pollution has drawn much attention towards itself. It must be one of the world's largest environmental concern due to the death rate caused. People have expectations of being safe in indoor environment till temperature and humidity, basis of comfortable conditions are found to be bearable. These expectations brought out the term Indoor Air Quality (IAQ) which has become key in determining the acceptability of indoor environment that includes all workplaces and homes (Dogra, 2013). People present in indoor environment are exposed indoor sources as well as outdoor pollution as the sources keep on penetrating into indoor environment. The ambient pollution keeps on penetrating in indoor environment due to which people in indoor have exposure to additional pollution (Colbeck et al. 2010). Report of the World Health Organization (WHO, 2005) asserts the rule of 1000 which states, “A pollutant released indoors is one thousand times more likely to reach peoples lung than a pollutant released outdoors.” Indoor air pollution is most severe for women and children, as these spent large amount of time in household.

The concentration of indoor pollutants depends on strength of indoor sources of pollutants, the ventilation of the building, activity scale responsible for pollution. Focusing on the indoor air pollutants apart from all the micro-contributors, particulate matter (PM) is solely responsible for larger portion.

There are several factors that affect the emission of PM in developing countries in contrast to developed countries. There are various unique sources those are not found in developed countries (e.g. burning of waste in open, cooking operations, use of dung and wood as a fuel), and these sources are never mentioned and studied. Burning of solid fuel is highly contributing source w.r.t indoor as well as ambient air pollution in developing countries, but not in case of developed countries. Also, much awareness is found in developed countries as people spend the more time in indoor microenvironments but this may not be true for people in developing countries. Finally, the poverty (especially energy poverty) levels and lower quality of life, leads certain sections of the population to have higher probability towards negative impacts on health. Thus, there is a need for a concerted global effort to generate exposure estimates for developing countries, yet most of our understanding of health effects and air pollution are derived from communities that are cleaner and more developed. There is an alarming situation for taking steps against air pollution in the developing countries like India, still most of the studies are undertaken considering communities which are cleaner and developed.

Talking about pollution solely blaming industrialization and urbanization but forgetting the fact that using solid fuel for combustion and cooking plays very important role. Particulate matter mainly results from combustion of unprocessed solid biomass fuels. Cooking is a task carried essentially in every household every day. Large number of people globally rely on traditional use of biomass for cooking. Maximum use of biomass as fuel for cooking is exhibited by African countries. India alone was having significant figure of 815 million people depending on solid biomass fuel such as wood, cow dung and other agricultural residues for cooking till 2014 (TERI 2015).

The factors responsible such as income, education, socio-economic status and age are found to be responsible to influence fuel choice (Andresen et al., 2005; Duflo et al., 2008; Dutta and Banerjee, 2014). Wood, cow dung and other agricultural waste are always locally and freely available. Thus, mainly indoor air pollution in India and all developing countries was poverty-driven. Result of which high concentrations of PM emissions are reported in low income or economically weaker sections of country. The straight forward solution to this problem was introduction of clean but cheaper fuel.

In recent years, however there is an increasing concern about airborne exposure from cooking. Indian household cooking needs long hours, minimum of 3 hours in the morning and 3 hours in the evening for a household meal. Because of their customary involvement in cooking, women's exposure is much higher than men's in case of household cooking. Young children are often carried on their mothers' backs while cooking is in progress and therefore spend many hours breathing smoke. Health effect is determined not just by the pollution level but also, and more importantly, by the time people spend breathing polluted air, i.e. the exposure level. Exposure levels are extremely high in case of commercial cooking as compared to household cooking. Commercial cooking is where food is prepared for the large number of people and the process is continuous all the day. Hence there was the need of the alternative fuel.

Liquid Petroleum Gas(LPG) simply known as propane or butane is flammable mixture of hydrocarbon gases. This is derivative of petroleum (crude oil). LPG is used for variety of uses. Mainly used in cylinders for cooking in household and commercial. Burning LPG releases particulate matter much lesser than that released from coal burning. Also, the amount of carbon dioxide released is less. Large temperature ranges in lesser time is achieved by LPG flame.

Thus, LPG is cleaner, efficient, is easy to use, reduce cooking time and significantly reduce emissions as compared to solid biomass.

Poverty and supply chain acted as major barriers in adoption of LPG as cooking fuel by each class of society. LPG was expensive and was not readily available due to limited distribution networks in starting. Recently government of India has launched UJJWALA scheme under which LPG connections are provided free of cost to five crore poor households. This has been treated as the rapid rollout of clean fuel for poor household as earlier these were exposed to the dangerous emissions coming from biomass burning. Also, in 2015, the Indian government launched the national Air Quality Index(AQI) with the aim of providing information of air pollution in relevant format for the general public using color coding index. The index is based on several key air pollutants including PM_{10} and $PM_{2.5}$, Ozone(O_3), Sulphur dioxide(SO_2), Nitrogen Oxides(NO_x) and Carbon Mono-oxide(CO). These steps proved revolutionary in determining the exposure levels using AQI and reducing them by LPG use. But it cannot be said that cooking done by LPG creates no indoor air pollution.

While giving LPG as remedy to solid fuel we have protected our family members against emissions where exposure levels are less but we also need to protect those who cooks for others as a profession i.e. Commercial Cooking. It cannot be said that cooking done by LPG creates no indoor air pollution. Indoor Air Quality of commercial cooking areas in India, where the food is prepared all round the clock for thousands of people daily like several religious places, factories, hospitals, hotels, college mess, mid-day meal for primary schools, etc. is still very poor.

Various types of recipes are prepared all the day. Indian and Chinese cooking style are declared as most polluting ones. In our country food is served with feelings and beliefs. The cooks use number of spices to bring the best taste in it. Various types of cooking oil, ghee is used in frying. Although the country is most rapidly developing country in world yet there are areas where we still have traditional beliefs ruling. One of such is our cooking practices.

Cooks are working for average time of 13 to 15 hours in a day. Many factors other than fuel are also contributing to the worst air quality in commercial kitchens. In India the implementation part of any scheme or law is very poor. Guidelines to be followed in construction of arena for the particular commercial purpose is never followed. This plays important role in increasing the concentration of pollutants. The number of workers working and amount of food that can be cooked is limited to the availability of workspace.

In most of the countries health of the employee is kept at higher preference than the quantity of work undertaken by them. In order to ensure safe and healthy working atmosphere, indoor air quality standards are enforced by law. More and more emphasis laid on developing environment friendly techniques, machinery and fuel used. Even the worker is himself highly aware for the working atmosphere. In the country like India, having large population no concern is shown for the working conditions by employer or the government

The commercial cooking is mostly involving large workforce and being carried out in inefficient spaces and have all the dangerous pollutants like particulate matter(PM), carbon monoxide(CO), polycyclic aromatic hydrocarbons(PAHs), nitrogen dioxide(NO_2) and Sulphur dioxide(SO_2). Exposure to these for the long duration and regularly brings long term health effects in the cooks like cancer, respiratory disorder, cardiovascular diseases, cerebrovascular diseases, visibility, etc. Each of the pollutant has the great potential to harm the human body but the respirable suspended matter(RSPM) is of great significance. More concerned are $PM_{2.5}$ and PM_1 which have most severe consequences. These are particles with a diameter of less than 2.5μm and 1μm. These can pass through the nostrils penetrating deep into the lungs, long exposures even sometimes acting lethal. Efforts are being taken up by the government and people of India to counter the causes of the outdoor air pollution. Still there are large number of studies done on ambient air pollution not on indoor air pollution.

The objective of this study is to:

- To measure the concentration levels of $PM_{2.5}$ and PM_1 in Hostel Canteen cooking area during cooking.
- To measure the concentration levels of $PM_{2.5}$ and PM_1 in sitting area of hostel canteen during cooking.
- Comparison of temperature and relative humidity in canteen cooking area with that of ambient atmosphere.

The inferences drawn from the present work may help in planning and execution to curb down the level of indoor air pollution to which the cooks and the inhabitants of the commercial cooking sector are exposed. Thereby, minimizing the health hazards by improving the Air Quality Index (AQI) where the commercial cooking is carried out.

CHAPTER 2

REVIEW OF LITERATURE

Clean air is of prime importance to sustain healthy lives of mankind and those of the supporting ecosystems which in return affect the human wellbeing (Rinki Jain, Karnika Palwa,2015).Air pollution is one of the great killers of our age," Philip Landrigan of the Icahn School of Medicine at Mount Sinai wrote in an article published in the medical journal The Lancet. In addition to land and water, air is the prime resource for sustenance of life. The success of a nation to improve air quality depends on the support of its citizens who are well-informed about local and national air pollution problems and about the progress of mitigation efforts. In a recent World Health Organization(WHO) estimates suggest that in the same year, more than seven million premature deaths were due to air pollution exposure, with more than 80% being in the Pacific and South Asian regions (WHO 2014). Air pollution is caused by human activities such as mining, construction, transportation, industrial work, agriculture, etc. Volcanic eruptions and wildfires are some of other causes but their effects are localized and are rare in occurrence. In addition to these there are several other unique sources which include funeral pyres (Chakravaty et al. 2014) and festive fireworks and biomass burning (Beigh et al.2013a; Pervez et al. 2015).

Exposure, a broadly used term used to reflect both qualitative and quantitative measures of a pollutant. It can also be defined in other ways, although the most general definition encompasses the amount of pollutant concentration and the duration of time an individual spends in contact with that pollutant (Moschandreas et al. 2002; Morawska et al. 2013). Various approaches for defining an exposure are discussed by Zartarian et al. (2004). A majority of the air pollution research efforts over last 50 years are comprised of characterization and speciation of outdoor particulate matter(PM) and its sources. Whereas outdoor PM concentrations are prime contributors to personal exposure(PE), they often do not correlate with, or are lower than levels of air pollutants individuals are exposed to (Monn et al. 1997; Huang et al. 2012). Exposure to air pollutants can occur through two major sources-personal exposure to outdoor or indoor air pollutants during daily activities (cooking, commuting or etc), and occupational exposure at the workplace.

Release of various gaseous emissions and particulate matter (PM) has been on the rise due to rampant industrialization. Anthropogenic emissions of various kinds are being released into the atmosphere are called primary pollutants like Oxides of Carbon, Nitrogen and Sulphur which also lead to the formation of new pollutants due to chemical reactions in the atmosphere, called secondary pollutants like Ozone(O_3), Peroxy Acetyl Nitrate (PAN) and Chlorofluorocarbons (CFCs). People are becoming aware about the ambient air pollution (AAP) as a prominent global threat to human health.

2.1 Scenario of ambient air pollution in India

Key sources of PM in India include vehicles, industries, power plants (coal combustion), dust, construction, biomass combustion (for cooking and heating) and waste burning (Liu et al. 2013; Pnat et al. 2015; Srimuruganandam and Shiva Nagendra 2012; Abba et al. 2012a). In 2010, 140 out of 176 cities were found to exceed the $PM_{2.5}$ National Ambient Air Quality Standard values (Gargava ana Rajagopalan 2015). The largest cities and the Indo-Gangetic basin have been identified as the areas with the most severe air pollution (Guttikunda et al. 2014; Ram and Sarin 2014; Dey et al. 2012). A number of studies have reported enrichment of elements associated with anthropogenic emissions in PM_{10} and $PM_{2.5}$(Pant et al. 2015; Shridhar et al. 2010; Sudheer and Rengarajan 2012), and similarly high PAHs concentrations have also been reported in several cities (Sarkar and Khillare 2013; Abba et al. 2012b; Pant et al. 2015; Cheng et al. 2013). In her first trade trip as UK Prime Minister, Theresa May's visit to India in November 2016 attracted a number of headlines, some of which claiming that her short trip to Delhi had a similar effect on her life as smoking 60 cigarettes on account of the levels of pollution being 15 times over world safety limits. The revised National Ambient Air Quality Standards (CPCB 2009) are notified for 12 parameters – PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, Pb, Ni, As, Benzo(a)pyrene, and Benzene.

2.2 Indoor Air Pollution

While we think of air pollution as a condition describing outside air, the air quality within your home is equally important. Cooking vapors, carbon monoxide from heating appliances, off-gassing of formaldehyde and other chemicals from furniture and construction materials, and second-hand tobacco smoke are all potentially dangerous forms of indoor air pollution Indoor air pollution - ranked among the top five environmental health risks to the public by EPA. Figures from the Institute for Health Metrics and Evaluation (IHME) shows that, 2.6 million people died prematurely in 2014 from illness due to indoor air pollution (IHME, 2015). According to a recent report by World Health Organization (WHO, 2014) globally, around 4.3 million deaths were directly or indirectly connected to indoor air pollution in 2012, the figure previously was 2 million in 2004 almost all in low and middle-income countries.

We expect highly congenial indoor environment with a hope that this environment will not be a threat for our wellbeing having appropriate temperature and humidity (Dogra,2013). It has been reported that about 70-90% of the human time budget is spent indoors (Nazaroff and Goldstein, 2015). IAP ranks fourth among global risk factors (WHO 2006). Weakening of immune system as a result of exposure to household air pollutants is most common affect seen (Mentese et al. 2015). Chemicals, combustions, inadequate ventilation and the construction of increasingly airtight buildings to boost energy efficiency have combined to make our indoor air a deadly threat. The important sources of exposure to air pollutant include solid fuel combustion, cooking, use of incense sticks/candles, use of printers, consumer products(sprays and deodorants, fresheners), Environmental tobacco smoke(ETS), kerosene lamps, varnishes, paints, household activities(cleaning and biological materials(pollen and mites) (Walllace 1995; Jones 1999; Spengler and Chen 2000; Meng et al. 2004; Najaroff 2004; Colbeck et al. 2010). (LONG et al. 2000; Diapouli et al 2013 and Norawska et al 2013) reported that infiltration of ambient aerosols and generation of particles due to reactions also contribute to the air pollutant concentrations in household air pollution. Meng et al. (2004) reported that ambient particles can contribute between 25 and 65% of total indoor particle load depending on the characteristics of the home. However Long et al.(2000) suggested that resuspension activities such as walking and dusting are two important sources for both fine and coarse particles in the indoor environment. Chen and Hildemann, 2009 reported that bioaerosols, human skills and the presence of pet animals may also influence the PM concentration. Recently Ma and Y Harrad 2015, reported that PAHs inhalation along with diet are two major routes of exposure to PAHs associated with indoor dust. Concentrations recorded in indoor microenvironments in our country are comparatively much higher than labels reported from other countries. The PM concentrations reported (20-1000 microgram/m3) till date shows variations between urban and rural areas Pant et al. 2016. Devi et al. 2009 reported $PM_{2.5}$ concentration ranging from 22.5- 165.2 μg/m^3 in indoor microenvironments in Kanpur. Massey et al. 2012 reported that indoor $PM_{2.5}$ concentration at roadside in Agra was recorded as 161±62 μg/m^3 while at urban site it was 109±48 μg/m^3. The concentrations were found to vary in summers (197-936 μg/m^3) and in winters and 34-60 μg/m^3 in summers across houses of different sizes in Delhi (Kulshretha et al.2008). Satsangi et al. 2014 recorded average indoor 2.5 concentrations of 89.7±32 μg/m^3 in Pune. However, Varshney et al.2015 reported relatively lower PM concentrations in Agra urban(45.33μg/m^3), roadside(36.71μg/m^3) and Agra rural(71.33μg/m^3) households. However, Havel et al.2016 reported 123.79±35.32 μg/m^3. Li et al 2010 reported that a wide range (20-748 μg/m^3) of indoor concentrations in hospitality venues with an average concentration of 207 μg/m^3

Naturally ventilated buildings allow infiltration of ambient air, which indicates that ambient air can significantly affect indoor air concentrations (Goyal and Kumar 2013). The poor ventilation often results in higher concentration of pollutants (Monkkonen et al 2005; Gadkari and Pervez 2007). A negative correlation between air exchange and indoor $PM_{2.5}$ concentrations were observed hospitality venues was reported by Lee et al 2010 which indicate higher $PM_{2.5}$ concentrations in poorly ventilated buildings. I/O of pollutants indicate rate of infiltration which vary significantly between naturally and mechanically ventilated buildings. In New Delhi I/O were found to range between 0.2 and 3.2 for $PM_{2.5}$ and 0.17-2.9 for PM_1(Goyal and Kumar 2013) and in Nagpur (Monkonnen et al 2005) 0.7-1.36 in urban houses. Rosati et al. (2008) reported use of ceiling fans also influences rate of resuspension as well as particle deposition in indoor microenvironments.

2.3 Statics of biomass fuel in India

A significant portion of households of India use traditional fuel like wood, coal, cow dung and kerosene (Balakrishnan et al. 2013; choi et al 2014), and other factors such as education, income and socio-economic status have been reported to influence fuel choice (Andresen et al. 2005; Duflo et al.2008; Dutta and Banerjee,2014). Energy choice is also related to the social and environmental justice argument since using LPG is associated with a higher cost, and the usage of solid fuel and/or kerosene is higher in case of poorer of the poor neighborhoods. According to Census 2011, in rural areas of the country where 86.5% of households completely depends upon solid biomass including firewood, crop residue, cow dung, coal, lignite and charcoal as primary fuel for cooking. Only 12.1% of the rural households depend on modern fuels including Liquefied Petroleum Gas (LPG)/ Petroleum and Natural Gas (PNG) as primary fuel for cooking. The rest depends on other fuel sources including biogas and electricity for the purpose of cooking.

In urban India, the proportion of households using LPG was under 2/3rd or 7.5% of those depending on traditional fuels for cooking (Singh and Gundimeda, 2014). Another study showed that 26.3% of the urban households depend primarily on solid biomass fuel sources including cow dung, coal, lignite, and charcoal. The percentage of families in urban India using kerosene for cooking has narrowed up almost to 1/3rd of the 2001 figure over last decade. Study done by Sahu et al (2012) demonstrates increase in consumption of LPG from 7.01 MT (Metric Tons) to 18 MT whereas a decrease in usage of kerosene has been noted i.e. from 11.30 MT to 9 MT for the year 2001 to 2011. It has been estimated that traditional fuels on combustion release at least 50 times more noxious pollutants than LPG(Smith,2003). Thirty years ago almost two thirds of the world's population was using solid fuels for their cooking which now has come down to 41%.

2.3 Brief introduction of Indian cooking

Cooking is a task carried in every household every day. In recent years, there has been great concern about airborne exposure from cooking. Commercial cooking is carried out where food is prepared for thousands of people all round the day like in religious places, hostel mess, factories, hotels or etc. In rural areas, biomass fuels like animal dung and agricultural residues are available without any additional charges to the user. So, there was less incentive in switching to cleaner and costlier fuels like LPG. The availability and ease of use plays important role for the choice of fuel (Gupta 2006). The children from low-income households are suffering more in acute respiratory infections when compared to children from high-income (rich) households in Tanzania (Bukalasa 2011).

Indian cooking needs long hours, minimum of 3 hours in the morning and 3 hours in the evening. So, in case of commercial cooking the cooks work for approximately for 15 hours in a day. Indian cooking also uses lots of oil, gee or butter to make the food tasty. These oil ghee or butter are used as frying medium in almost every type of cooking. This produces oil vapors which are inhaled by cooks (A Mandal and S Mandal). The location of kitchen premises is also reported to play an important role in affecting the air quality indoors. According to latest Census report, 31.5% of households in India do not possess a separate kitchen area and thus all the cooking activities takes place in a multipurpose room. In Bihar, Jharkhand, Madhya Pradesh, and Uttar Pradesh, over 30% of the households as well as commercial kitchens carry out cooking in combined arena (Kumar and Gupta, 2013). Hence, results in generation of indoor smoke leading to particulate pollution. Cooking activities without a separate kitchen area results in increased risks for cooks being exposed to IAP (Singh and Jamal, 2012).

2.4 Concentration of particulate matter during cooking

The oldest and newest class of air pollutants includes particles in different phases. They were the first category of pollutants to be widely monitored in the form of soot primarily and later were reported as the mass of total particle levels collected on filters (Anonymous, 1912; Meetham, 1964). The term "Particulate Matter" (PM) is extensively used for mix of very small particles of dust, pollen, ash, soot, metals and other chemicals found in atmosphere. They may be classified as natural and anthropogenic; primary and secondary; fine, coarse and ultrafine as previously described in many studies (Perrino et al., 2011; Singh et al, 2014; Taneja,2014).

Exposure to PM is a global risk because it has been associated to a number of noxious health outcomes. Many recent studies relate exposures with generation of oxidative stress. Particle toxicity can vary based on chemical constituents (e.g. trace metals and polycyclic aromatic hydrocarbons(PAHs)), that can trigger inflammation also (Valavanidis et al.2008; Shah et al.2013; Kelly 2003). Exposure to PM has been associated with diseases and even death due to respiratory, cardiovascular and cerebrovascular diseases (Harrison and Yin 2000; Chen and Lippmann 2009; Raaschou Nielsen et al.2016). In Indian cities PM levels are around 4-5 times higher than those in the US cities (WRI, 1996). $PM_{2.5}$ is of specific concern because it contains a high proportion of various toxic metals and acids. Aerodynamically it can penetrate deeper into the respiratory tract and reach up to lungs. A 20-year Children's Health Study in five California communities in and around Los Angeles has highlighted the impact of $PM_{2.5}$ on lung function among children. The study found that $PM_{2.5}$ particulate matter has a greater impact on health than PM_{10}, primarily due to the ease of bloodstream penetration by smaller particles (pat navin,2015). More than 50% of the population in India lives in areas where ambient $PM_{2.5}$ levels exceed the annual $PM_{2.5}$ India National Ambient Air Quality Standards(NAAQS), and less than 0.01% of the population lives in areas that meet the guidelines by WHO of $PM_{2.5}$ levels (Brauer et al. 2015). Between 2000 and 2010, $PM_{2.5}$ concentrations have been reported to increase at an alarming rate in several Indian cities including Delhi, Kolkata, Kochi, Mumbai, Patna, Amritsar and Jamshedpur (Dey et al. 2012). Only a few studies have been made on PM_1 concentrations such as its concentrations were found to be in the range of 31-199 μg/m^3 in Kanpur city (Chakravarty and Gupta 2010) whereas in Agra average concentrations range from 112 μg/m^3 at a roadside location to 104 μg/m^3 at an urban site (Massey et al. 2012).

In contrast to Europe, where only 10-14% of the total population lives in areas that exceeding the European $PM_{2.5}$ guideline value (EEA 2014). In 2011, the Central Pollution Control Board(CPCB) documented a 6-city source distribution study which included characterization of ambient PM as well as sources (CPCB 2010; Patil et al. 2013). In developed countries relatively, lower concentrations were reported. In the USA a study reported, median $PM_{2.5}$ concentration was reported as 14.4 and 15.5 μg/m^3 for indoor and outdoor environments respectively (Meng et al. 2004). In Oslo (Norway), median $PM_{2.5}$ concentrations of 5-7 μg/m^3 and 6-8 μg/m^3 were reported for indoor and outdoor environments respectively (Lazaridis eta al. 2008; Johannesson et al. 2007). Hence it is clearly states that indoor as well as outdoor concentrations of PM in cities of developed countries are much lesser then those of developing countries which is an important implication for exposure levels.

2.5 Health Impacts of air pollution

Premature deaths from air pollution are soothed in China. China which is always ahead India in terms of pollution problems and population. That steadiness is seen partly because China has laid fines and criminal charges to crack down on pollution. Whereas Indian government was focused on economic growth rather on protecting air quality and the environment. “There is a huge amount of data linking outdoor and indoor air pollution with adverse health effects, including acute and chronic disease, exacerbations of chronic disease and death,” said Dr. Barry Levy, adjunct professor of public health at Tufts University School of Medicine.

A detailed comparative study was made by Behera and Jindal (1991), between the type of fuel used and the percentage of occurrence of respiratory symptom that reported Dyspnea and postnatal drip to be higher in women using mixed fuels. There have been many researches on complicated organic matters, including PAHs. These are formed and released in atmosphere from food during certain cooking processes especially during frying which probably causes additional cancer risk among commercial cooks (Shields and Harris, 1995). Reports (Mishra, Reatherford & Smith, 1999) reveals that the usage of biomass fuels for cooking considerably increase the risk of tuberculosis in India. According to the World Health Organization (WHO) these deaths are due to the following diseases like pneumonia, stroke, ischemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer.

In India, the Global Burden of Diseases(GBD) study stated both AAP and IAP are the key risk factors in terms of diseases for the Indian population (Lim et al.2012), IAP has been reported as one most critical social determinant of health in India. (Cowling et al.2014). In India nearly 1000000 premature deaths are due to air pollution exposure (PHFI 2014). In Delhi alone, between 7350 to 16200 premature deaths directly linked with PM exposures (Guttikunda and Goel 2013). Today in India 14.7 people in every 100,000 die of particulate matter related illness (WHO, 2015*)*.

When a glance is made at the public health statistics of India main attribute is IAP. The Comparative Risk Assessment exercise is done as a part of Global Burden of Disease Project (2010) by WHO. The disease burden estimated for IAP in India for 2015 was reported elevated than the earlier estimates given in GBD-2010 (Smith et al. 2016). The current estimates show that around 400 million people in India are exposed to the adverse health effects of indoor air pollution based on the traditional practices. Around 875,000 deaths and loss of 16.9 million Disability Adjusted Life Years (DALYs) can be attributed to poor ventilation and cooking methods in case of indoor air pollution by cooking (GBD 2015).

In their Mysore study, Rechkemmer et al. (2005) identified women extremely prone to exposure of fine particulates released during domestic fuel combustion leading to disorder cataract (Pokhrel et al., 2005, Zodpey et al., 1999). IAP has been identified as a cause of cancer of lung, upper aero-digestive tract and cervix. Among these the lung cancer is the most characterized (IARC, 2006). Relationship between cooking smoke and pulmonary tuberculosis was established in a tuberculosis prevalence survey conducted by Kolappan and Subramani (2009in Tiruvallar districts of Tamil Nadu and in a case control study among adult women in Chandigarh accomplished by Lakshmi et al. (2012).

CHAPTER 3

METHODOLOGY

3.1 STUDY AREA

As the basic objective to conduct this study was to assess the air quality in commercial kitchens, hostel canteen of a college was selected as study area. The canteen was located in the interior of college campus i.e. away from urban roadway. Area had a good cover of trees. The cooking area of canteen consists of rectangular hall which is equipped with many large gas burners used for bigger vessels and the combined burners used for chapati making and some smaller gas stoves for minor cooking practices, all running on LPG. Total cooking area of canteen hall was 600 square feet with roof height of 14ft. Two windows were provided in the hall for natural ventilation. Above two windows artificial exhausts were installed above windows and two chimneys were also fitted in cooking area.

Attached to this hall was the sitting area with the capacity of approximately 800 students. Only the plastic curtain separation exists between the cooking area and sitting area as there was continuous movement of workers going on for the supply of food. Sitting area was air conditioned.

The food was prepared for 1800 students in the canteen. Number of workers and cooks involved vary between 20-25 and 15-20 respectively. The cooking started from 09:30 AM in the morning with the lunch preparation starting from 10:00 AM to 12:00 AM. Again from 12:00 AM to 1:30 PM the burners were kept fired for chapati making and also the already prepared food was continuously heated. In continuation all the dinner items leaving chapati were prepared along with evening snacks from 2:00 PM to 4:30 PM. Even snacks mainly involved fried items like bread pakora, chips, chowmein, etc. Meanwhile, till the dinner time on-demand food items were prepared in canteen continuously.

3.2 EQUIPMENT USED

HAZ-DUST SAMPLER
Environmental Particulate Air Monitor(EPAM) -5000

EPAM-5000 is a highly sensitive real-time particulate monitor. It is designed for ambient as well as indoor air quality applications. It has a light scattering nephelometer and a filter gravimetric air sampler combined together. This unit has traditional filter techniques with real-time monitoring methods which is a great overcome on the drawbacks of many other monitors. EPAM-5000 uses the principle of light scattering of an infrared radiation through which immediate and continuous values of concentration in mg/m^3 of airborne dust particles is obtained. The infrared light source is positioned such that it makes 90-degree angle to a photo detector. When the particles enter the beam, they scatter light.

The machine shows immediate display and also has data storage of particulate matter concentrations. Data of concentration of PM is obtained in form of graphs. Sampling rate can be adjusted from 1 sec, 10sec, 1min and 30min. PM_1, $PM_{2.5}$ and PM_{10} all three particulate matter can be traced through this machine by using the suitable sampler. Machine has an outstanding advantage of data storage of approximately 5years.

3.3 SAMPLING PROCEDURE

Sampling was done for calculation of particulate matter ($PM_{2.5}$ and PM_1) concentration. Every 1-minute data have been recorded by the instrument. Readings were taken continuously for 1hour. Equipment was kept at height of 1 to 1.2 meters above the ground at the nose level. Readings were taken consecutively for seven days from 23rd of May 2018 to 29th of May 2018. Readings were taken in cooking area, sitting area and outside kitchen. Along with the particulate matter concentration temperature and humidity were also noted down.

In order to estimate the already present or ambient contribution to PM concentration inside mess the readings were also taken during non-cooking hours i.e. before cooking. The concentrations were recorded in mess after cooking. Readings were also taken differently for non-vegetarian food cooking and vegetarian food cooking. Also, one day in a week in mess Chinese food was cooked, readings were taken there also, to estimate the variation in emissions as Chinese cooking style has been declared as most polluting in world. In order to estimate the flow of particulate matter from cooking area to sitting area, the readings were taken in sitting area where students were eating food.

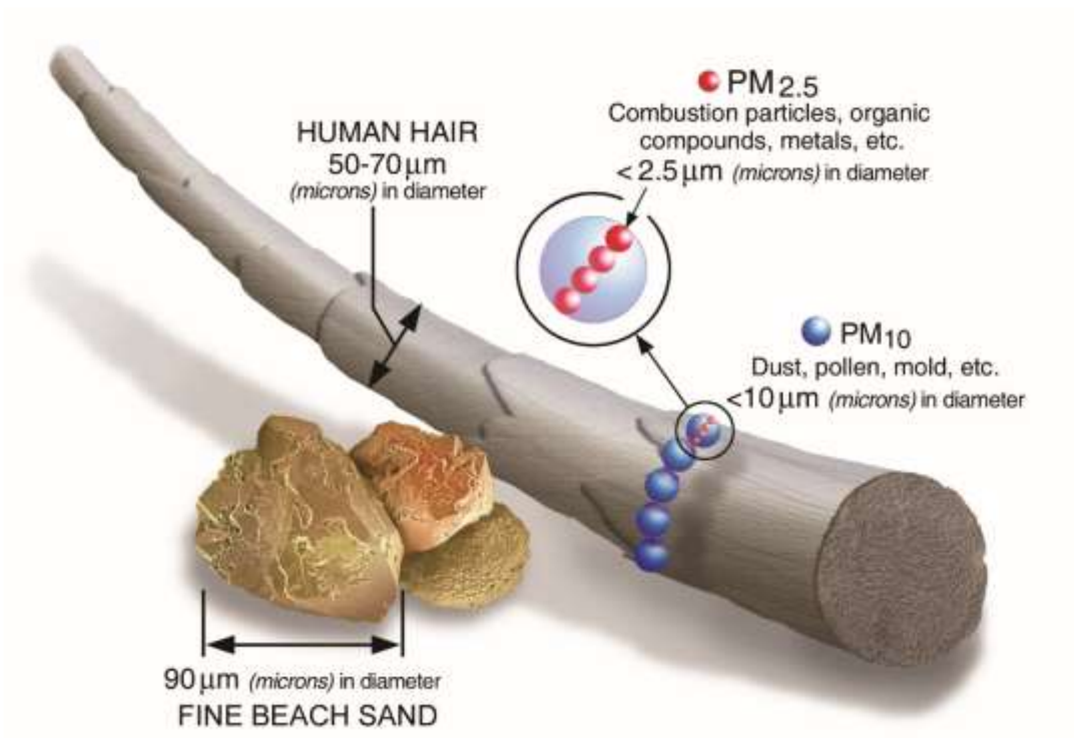
CHAPTER 4

RESULTS AND DISCUSSIONS

Results of the study are presented in this chapter. Variation between concentration in cooking area during cooking and non-cooking hours, comparison between the concentration levels of $PM_{2.5}$ and PM_1 in cooking area at sampling time and in sitting area are discussed. Comparison between temperature and humidity of cooking area and ambient and the possible reasons for it are also discussed.

4.1 CONCENTRATION LEVELS OF $PM_{2.5}$ AT THE COOKING AREA

The sampling for the $PM_{2.5}$ concentration level was measured using EPAM-5000 in the hostel canteen cooking area and sitting area. Sampling was done for the concentration level present in cooking area before cooking for the started, during lunch preparation and during dinner preparation. Sampling was also done in the sitting area to measure the concentration present.



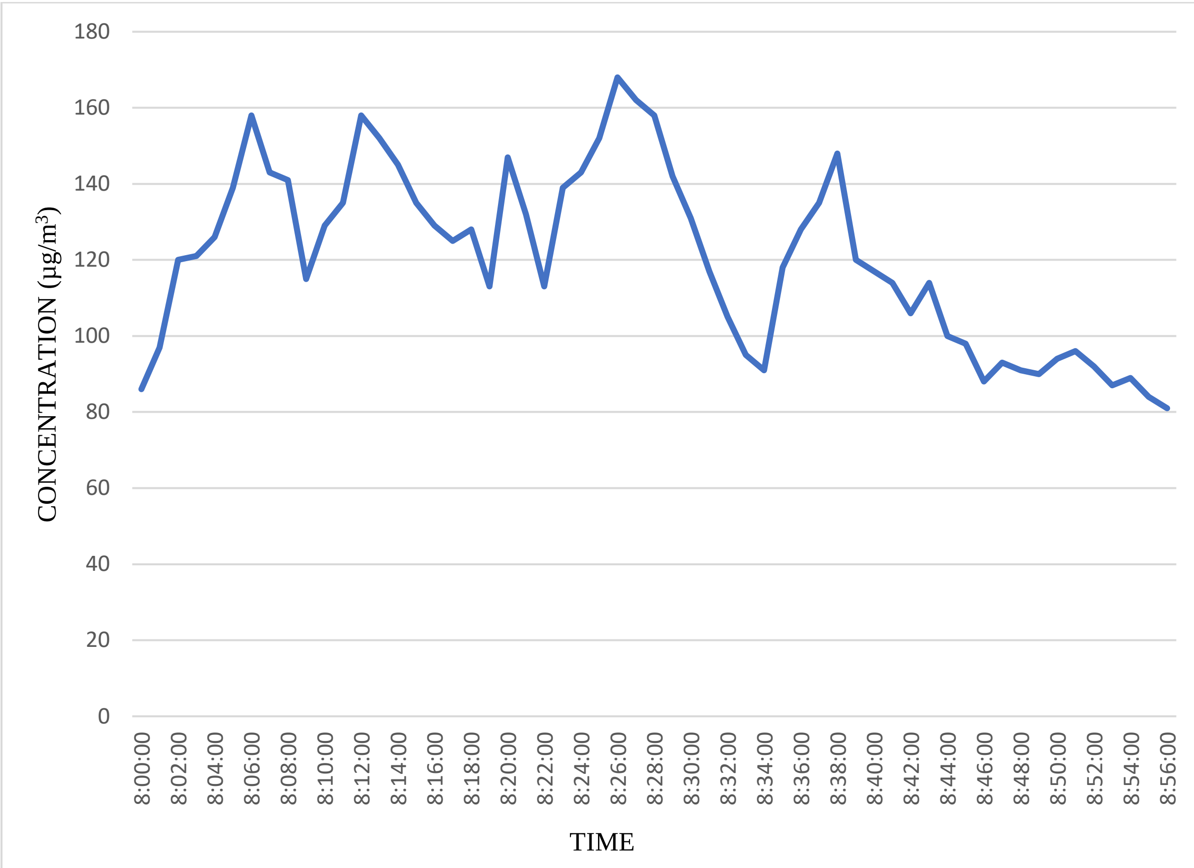


Figure 4.1 $PM_{2.5}$ Concentration before cooking

Figure 4.1 shows the variation of $PM_{2.5}$ concentration levels in cooking area during sampling done in morning before any kind of cooking activity is started. The average concentration levels were found to be 120.57µg/m^3.

Maximum value concentration 168µg/m^3 and minimum value 80µg/m^3. The peak occurred in graph may be due to start of activities in canteen like labor movements, opening of doors and windows, etc. The graph at the end shows concentration values near about 84 µg/m^3.

No dusting of floor or any cooking activity was performed in the cooking area while sampling was done. This ensured that the values obtained represent the standby concentration level in cooking area resulted from previous day cooking and to which the workers sleeping inside were exposed at night.

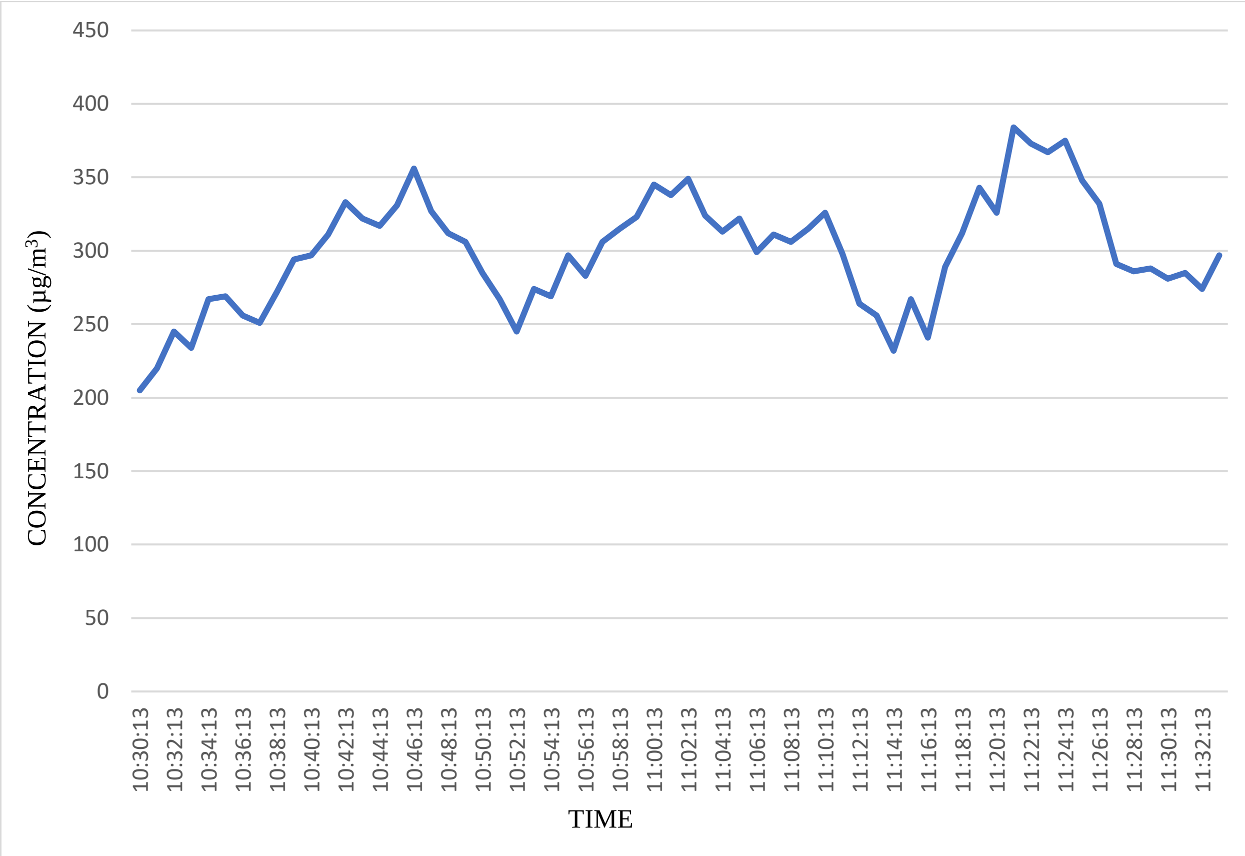


Figure 4.2 $PM_{2.5}$ Concentration during lunch preparation

Figure 4.2 shows the variation of $PM_{2.5}$ concentration levels measured in cooking area during lunch preparations. The concentration levels were found maximum to 384µg/m^3 and minimum to 232µg/m^3. The average concentration level was obtained to be 299.153µg/m^3.

Rising graph may be obtained as the particulate matter was continuously getting accumulated on account of various cooking activities going on in cooking area simultaneously. Sudden increase was seen whenever the stirring or mixing of the food item being prepared was done. As all the vessels in which cooking was done were open mouth the emissions escape into the air. These emissions are of oil/fats used for cooking, spices, etc. This may have contributed to the occurrence of peak.

Temperature of the cooking area was noted to be 48℃ which was 10℃ more than that outside.

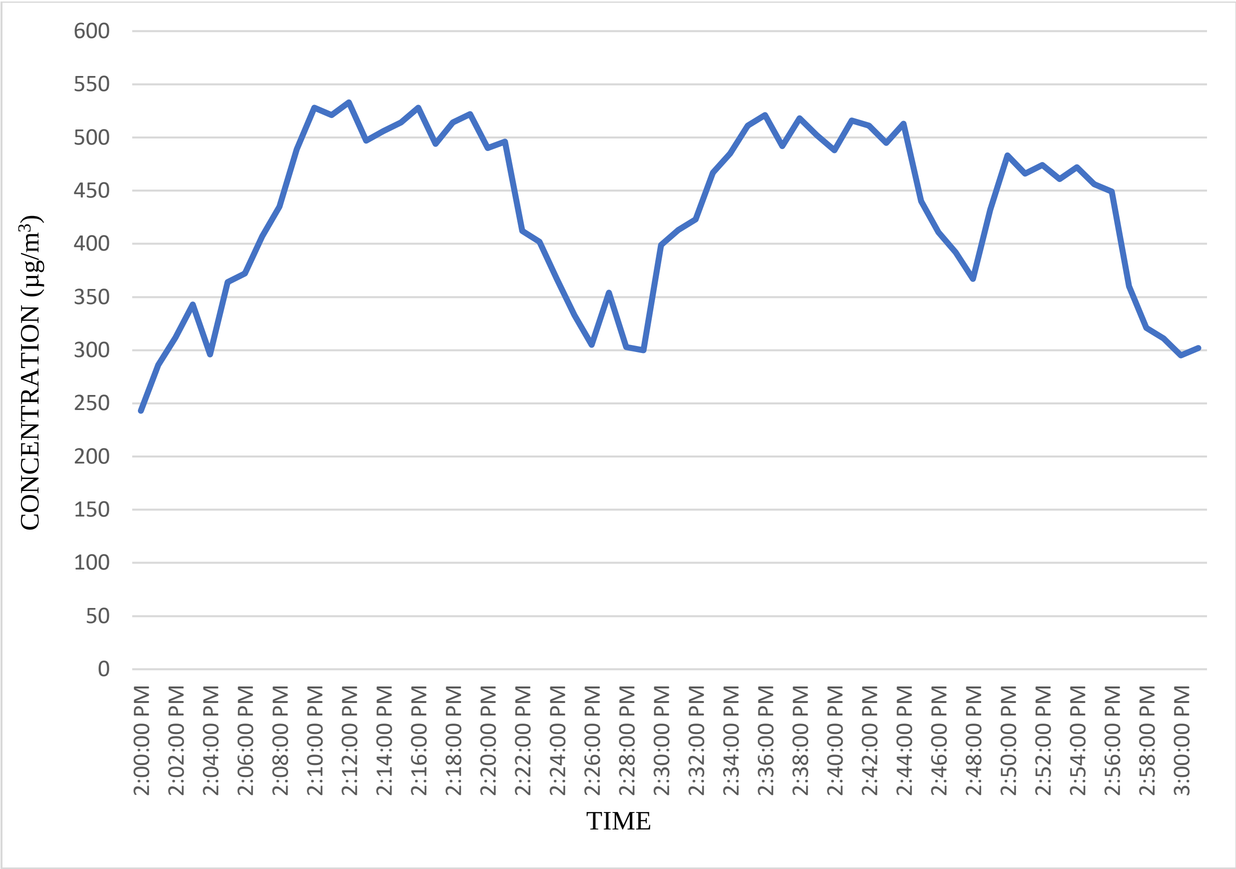


Figure 4.3 $PM_{2.5}$ Concentration during dinner preparation

Figure 4.3 shows the variation of concentration of $PM_{2.5}$ for sampling done during dinner preparation in hostel canteen. The average concentration level was found to be 439µg/m^3. The concentration was found to be maximum up to 533µg/m^3.

Accumulation of particulate matter or resuspension in area due to lack of sufficient ventilation provided in cooking area. For dinner more number of food items were prepared. Apart from this, frying was involved everyday in dinner preparation as per canteen menu. All of the mentioned factors may have contributed to highest value of concentration levels of $PM_{2.5}$ among the concentration levels obtained during sampling done for before cooking and lunch preparation.

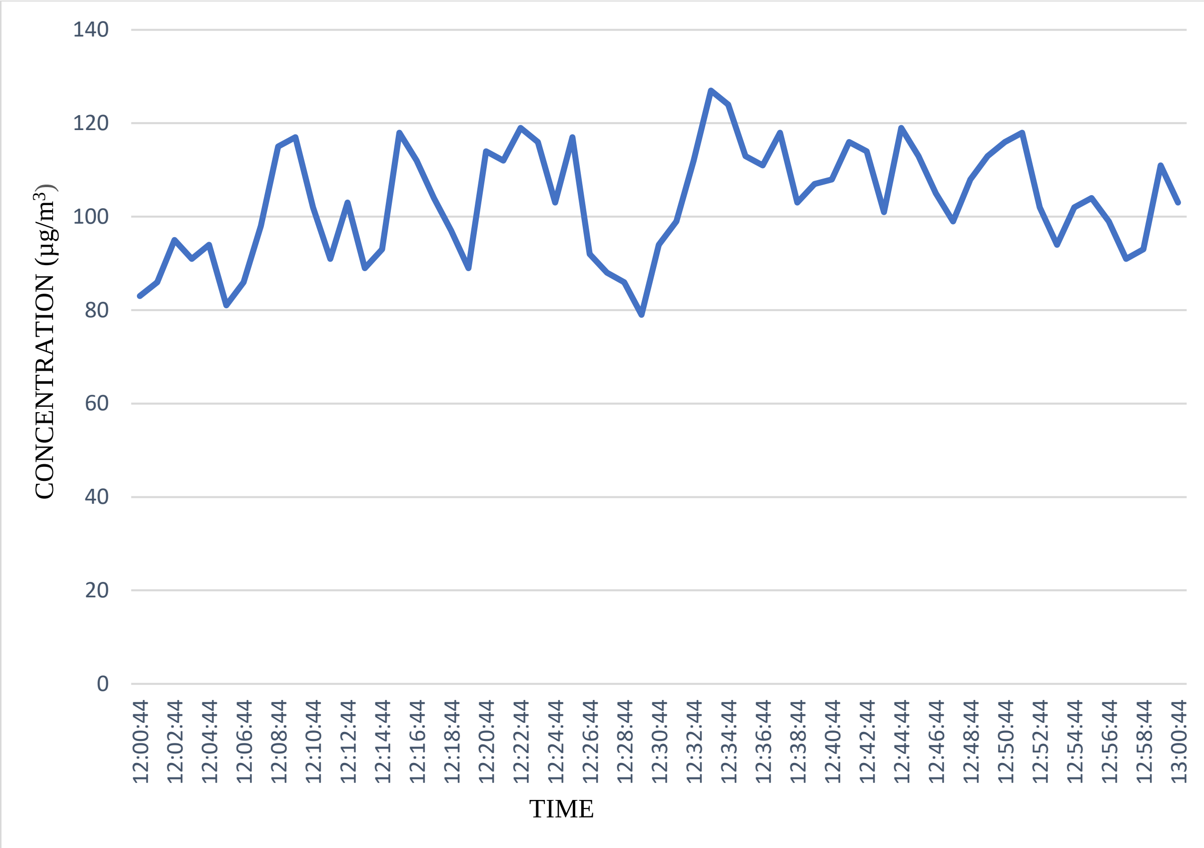


Figure 4.4 $PM_{2.5}$ Concentration in sitting area

Figure 4.4 shows the variation of $PM_{2.5}$ concentration level during the sampling done in the sitting area of hostel canteen where students sit and eat food. The average level of concentration was found as 103.393µg/m^3.

This value was measured when sufficient natural ventilation was provided. These values show that the high concentration of PM inside kitchen area move towards the sitting area through the connecting door between kitchen area and sitting area. Although the door has plastic curtain to stop free flow of PM yet there was some transfer.

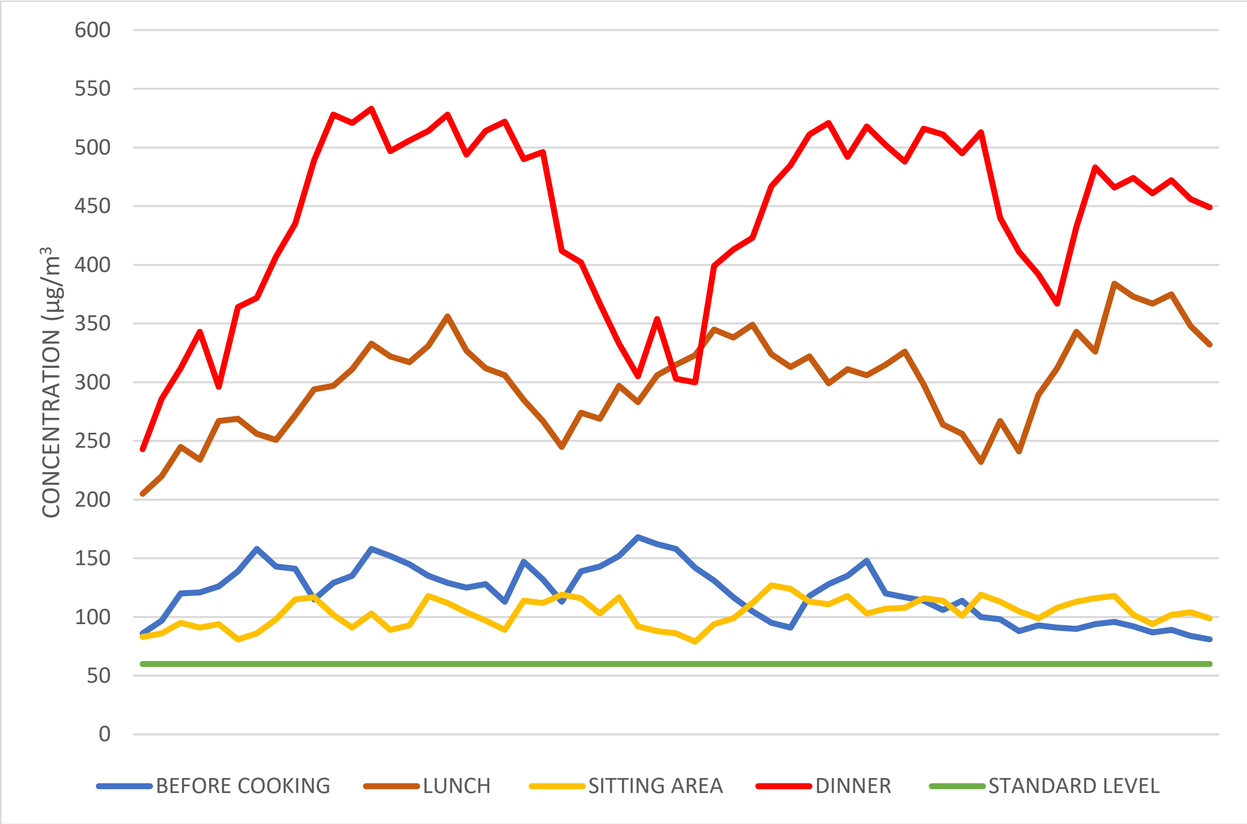


Figure 4.5 $PM_{2.5}$ concentration at different time in day

The U.S. Environmental Protection Agency (EPA) has set a $PM_{2.5}$ standard for outdoor air at 15µg/m3. California has set an even stricter standard of 12µg/m3. In India according to National Ambient Air Quality Standards the concentration levels of particulate matter must be less than 60µg/m^3 in ambient air for residential or industrial area and must be less than 40µg/m^3 in case of sensitive area. These standards are set because exposure to concentration levels more than this will create negative health impacts. These standards are set for ambient air quality, definitely the permissible concentration levels for indoor air quality must be less.

In all the four categories of sampling done in the study for $PM_{2.5}$, the concentration level was found to exceed these standard values.

$PM_{2.5}$ particles are so light that they can stay in the air for days. The suspension concentration of $PM_{2.5}$ was found in the cooking area where many workers sleep at night. Sleeping in such an environment will put the workers into serious health issues.

As the results show high concentration levels of $PM_{2.5}$ during lunch preparation yet there were no safety masks provided to the cooks in the canteen. They were directly exposed to the emissions for long cooking hours.

Special attention was grabbed by the concentration levels obtained at the time of dinner preparation. Frying operation alone was found to increase the levels drastically. Similar results for frying operations were reported by Abdullahi et al., 2013.

Results cleared the fact that not only cooks in commercial cooking area but the guests for whom the food is prepared by them are also exposed to the high concentration levels of $PM_{2.5}$.

The results clearly indicate that if cooks are made to expose to such high level of concentration of particulate matter for long hours continuously than even the people sitting outside cooking area and enjoying the food will be affected. These values would be more in case live cooking kitchens where the guests enjoy the cooking done by cooks infront of them.

4.2 CONCENTRATION LEVELS OF PM_1 AT THE COOKING AREA

The sampling for the PM_1 concentration level was measured using EPAM-5000 in the hostel canteen cooking area and sitting area. Sampling was done for the concentration level present in cooking area before cooking for the started, during lunch preparation and during dinner preparation. Sampling was also done in the sitting area to measure the concentration present.

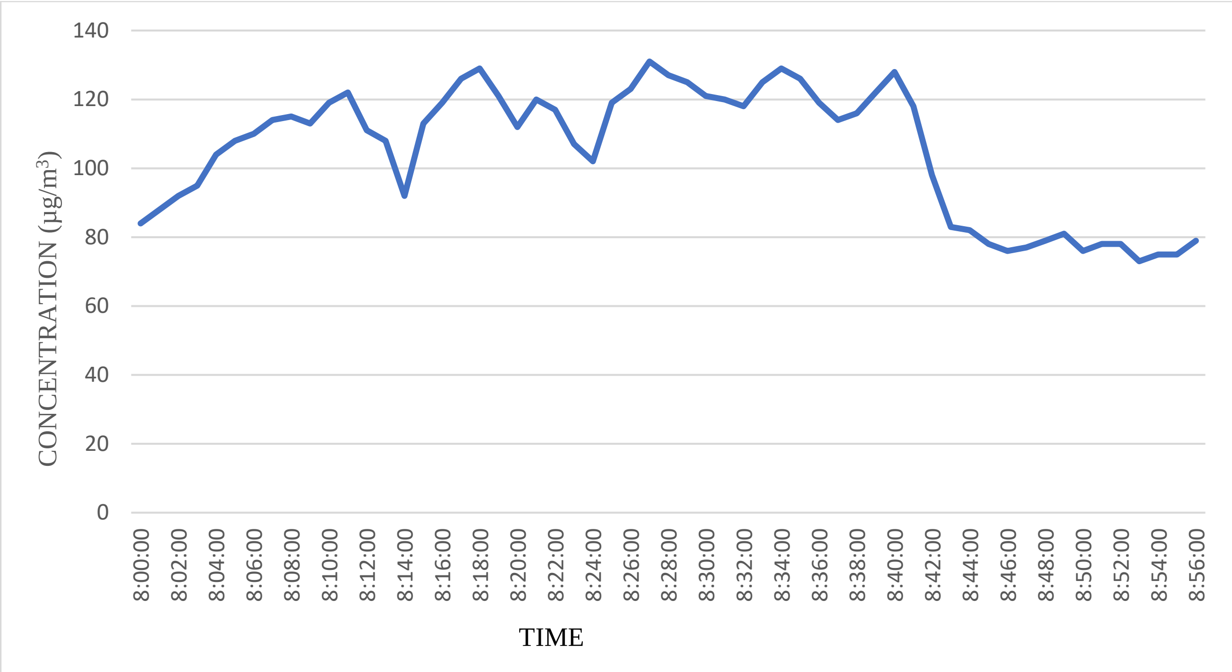


Figure 4.6 PM_1 concentration before cooking

Figure 4.6 shows the variation of concentration level of PM_1 in cooking area during sampling done early morning before any cooking actually started. The average value of concentration was found to be 105.438µg/m^3. The graph has the almost horizontal ending showing the concentration level to become constant.

The concentration increases to higher values the possible reason for this might be activities like movement of cooks, unloading the raw vegetables from packed bags for the day, etc.

These concentration levels are believed to be present in the cooking area at night also as these are result of whole day cooking. In most of the commercial cooking places workers sleep at night in these cooking areas. Hence are exposed to particulate matter concentrations resulting in severe health related consequences.

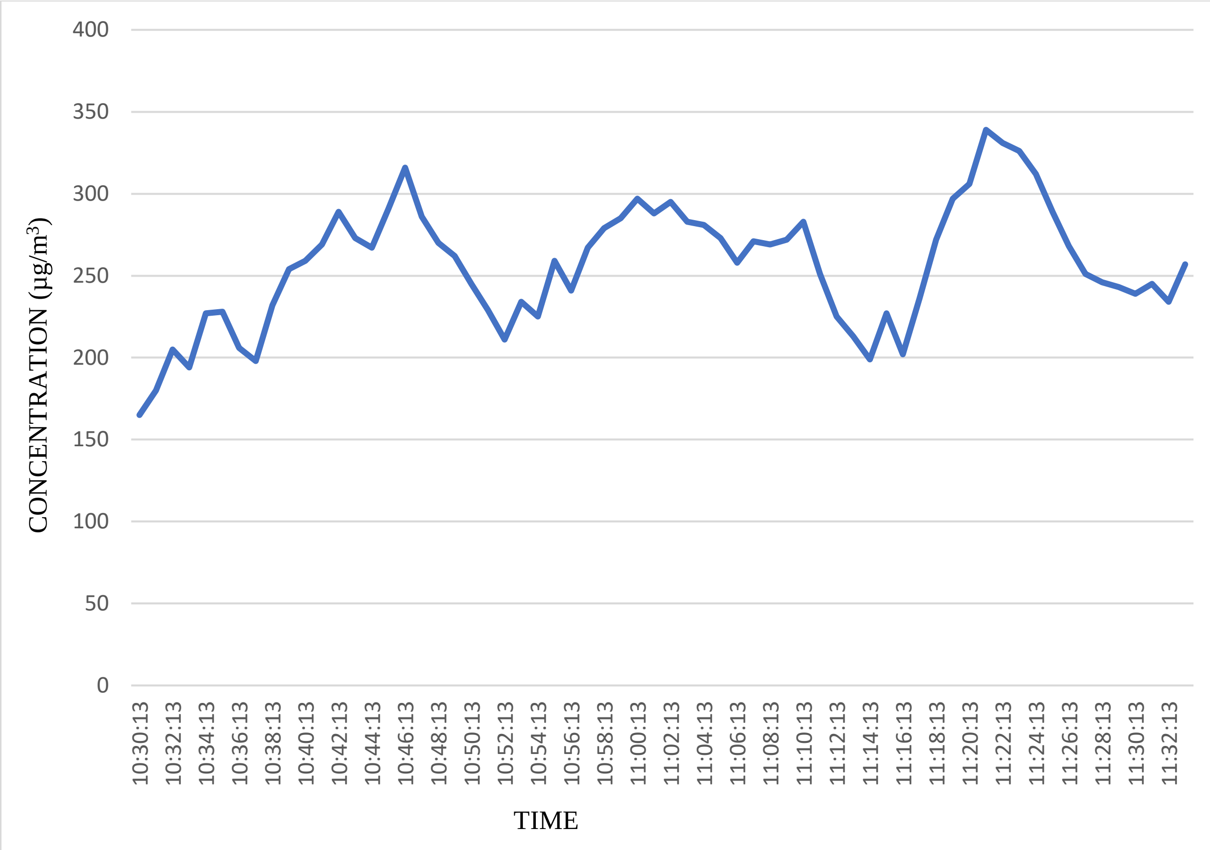


Figure 4.7 PM_1 concentration during lunch preparation

Figure 4.7 shows the variation of concentration level of PM_1 in cooking area during sampling done during lunch preparation going in canteen. The sampling was started with turning on of burners, so the graph has increasing values of concentration. The average level of concentration was found to be 256.625µg/m^3.

Simultaneously three big LPG stoves were running releasing high heat. Many activities were carried at one time associated with preparation of vegetables curies, Daal and Rice, releasing vapors in large amount in the cooking area. As all the vessels were open at the top so there was the free passage for the particulate matter to escape in the air. Contribution of these all factors may have taken the concentration levels to cross 300 µg/m^3 which started from 158 µg/m^3. Temperature of cooking area reached to 48℃ while it was 37℃ outside cooking area.

The concentration levels of 256.625µg/m^3 is severe for the Cooks cooking food for hours in this space loaded with such high particulate matter concentration levels.

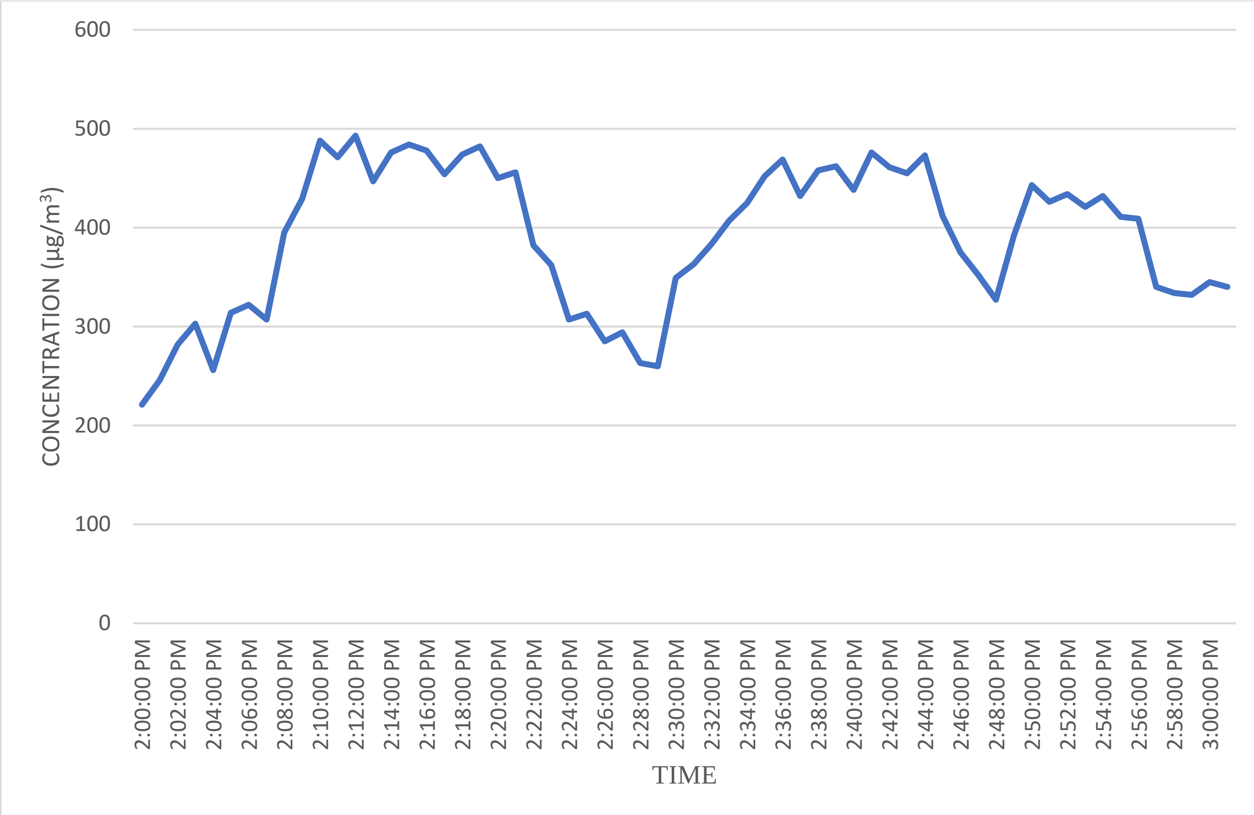


Figure 4.8 PM_1 concentration during dinner preparation

Figure 4.8 shows the variation of PM_1 concentration levels in cooking area obtained in sampling done during dinner preparation. The concentration levels were obtained under natural ventilation and two exhaust and one chimney condition. The average concentration level at nose height was 385.69µg/m3. The concentration value was observed to remain almost 335µg/m3 in the end of sampling duration.

The dispersion in ambient air of such particulate matter concentration levels from area having less natural ventilation as in canteen area is almost negligible. Hence part of such high values of concentration may be contributed by the accumulated particulate matter in the cooking area due to continuous cooking activity going on in canteen. The rise in the concentration levels were noted when oil was heated or when vegetables were put in hot oil or when mixing was done of ingredients in the pans. The reason for stabilizing of reading in the end may be the finish of major cooking.

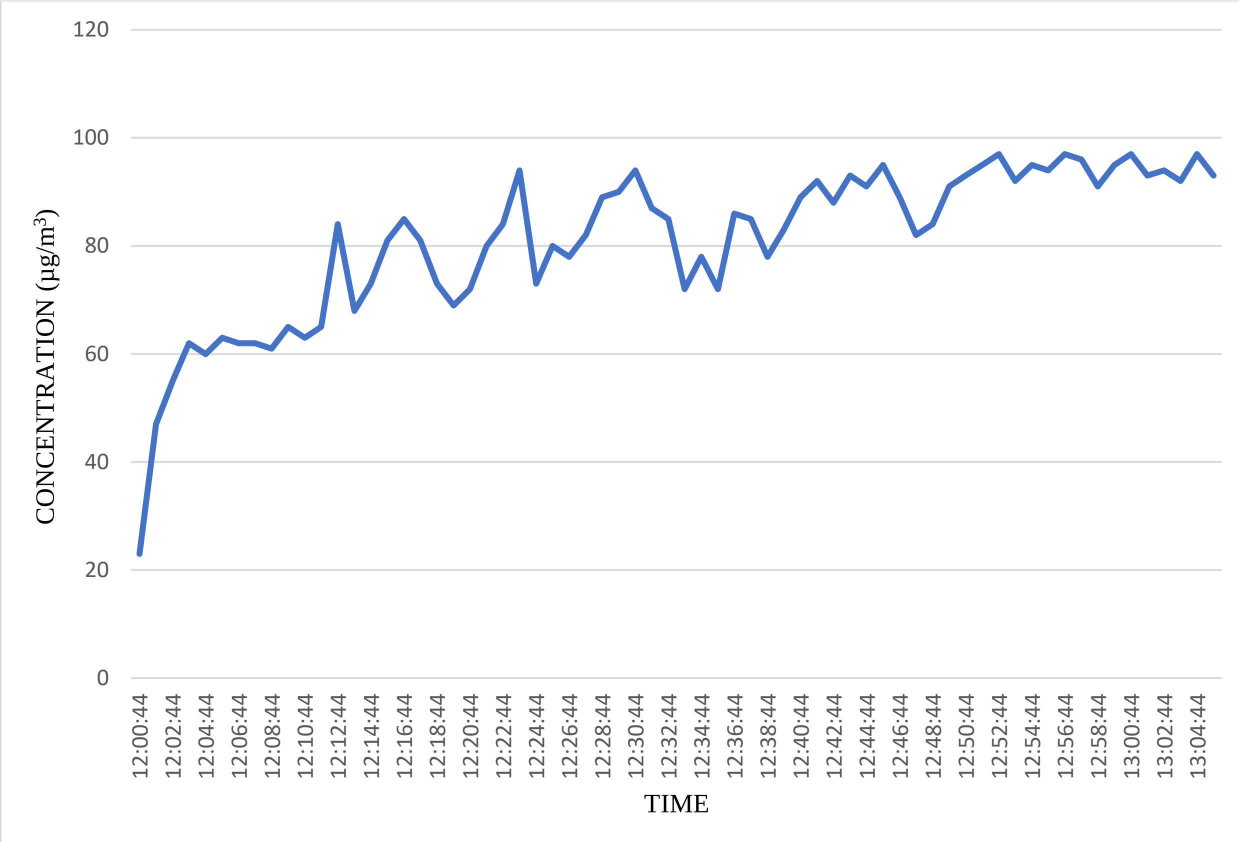


Figure 4.9 PM_1 concentration in sitting area

Figure 4.9 shows the variation of PM_1 concentration levels in sitting area during sampling done when students were having lunch in canteen. The average concentration level was obtained as 81.04µg/m3. The reason for concentration levels in sitting area may be less because of plastic curtain partition between cooking area and sitting area. Due to the high temperature in cooking area, the dispersion of pollutants take place towards sitting area. Also, frequently removal of curtain for the movement of worker to bring the food items from cooking area to sitting area. This may be reason for the sudden increment in concentration levels of PM_1 in sitting area.

Total area of windows and number of exhausts in sitting area were found to be more than that in cooking area. Hence the concentration levels were less as compared to the concentration levels in cooking area. The values were also less than the concentration levels in cooking area before cooking for day started.

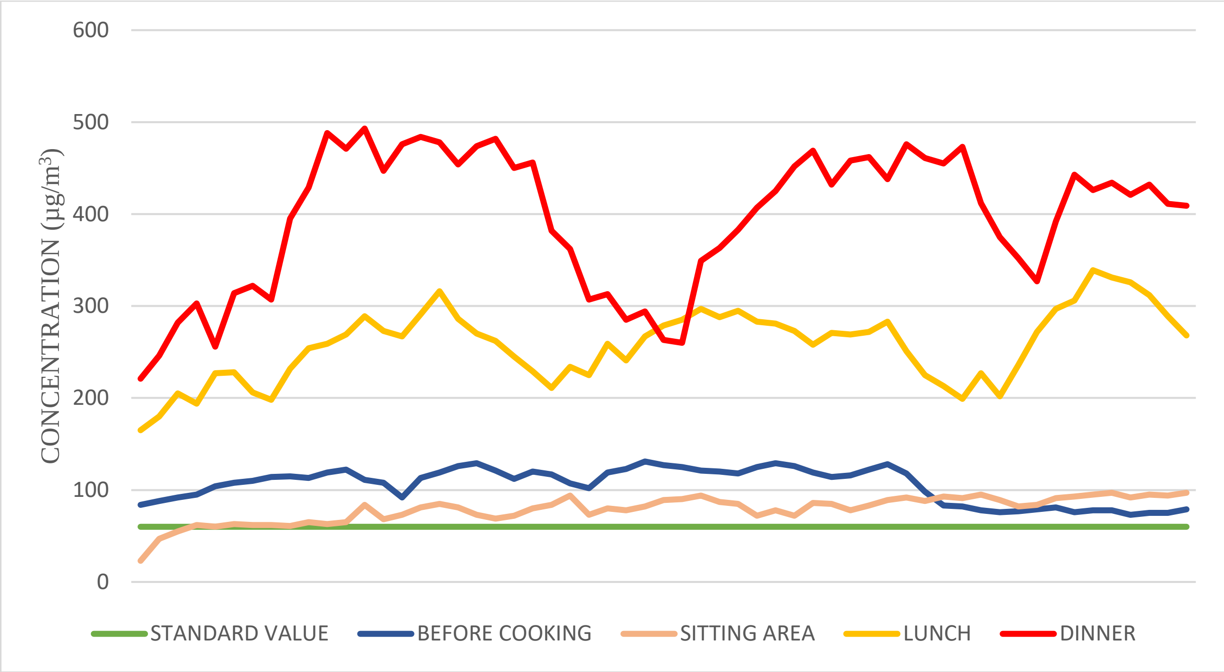


Figure 4.10 PM_1 concentration at different time in day

Figure 4.10 shows the combined plot of concentration level of PM_1 during sampling done at different time in a day in the cooking area. The results clearly indicate the increasing concentration levels of PM_1 from the morning when no cooking activity was done to the dinner preparation time.

There are no set standards in India to compare the concentration levels of PM_1 for indoor as well as ambient environment. PM_1 are so small that they can pass easily through the body's natural preventive mechanisms to the deep interior parts of the lungs. Certain people are more sensitive to the particulate matter, sometimes regardless of chemical composition. It has been reported in many studies that the sheer number of particles and their cumulative surface area may spark a reaction in these people. On this basis the standard concentration level of PM_1 has to be less than that of $PM_{2.5}$. Figure 4.10 clearly indicates that the concentration levels in all four sampling were more than that of $PM_{2.5}$ standard for ambient air.

Cooks were found working in such high concentration levels for hours continuously without any masks or other Personal Protection Equipment(PPEs).

4.3 COMPARISION OF $PM_{2.5}$ AND PM_1 AT DIFFERENT TIME IN DAY

The concentration of $PM_{2.5}$ and PM_1 when plotted simultaneously then it was observed that the concentration of PM_1 was always lesser than the concentration of $PM_{2.5}$.

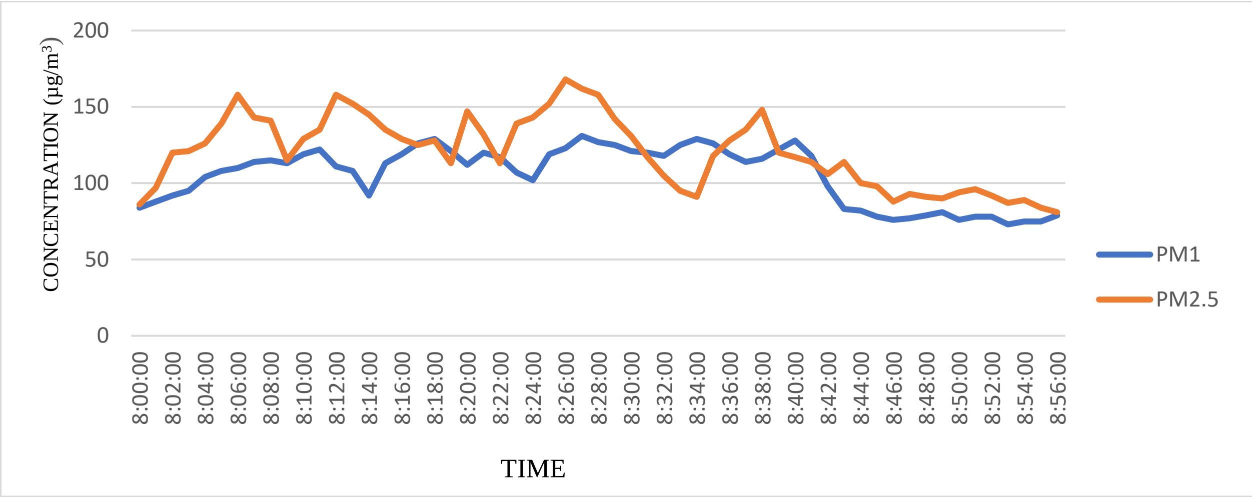


Figure 4.11 Variation of $PM_{2.5}$ and PM_1 concentration before cooking

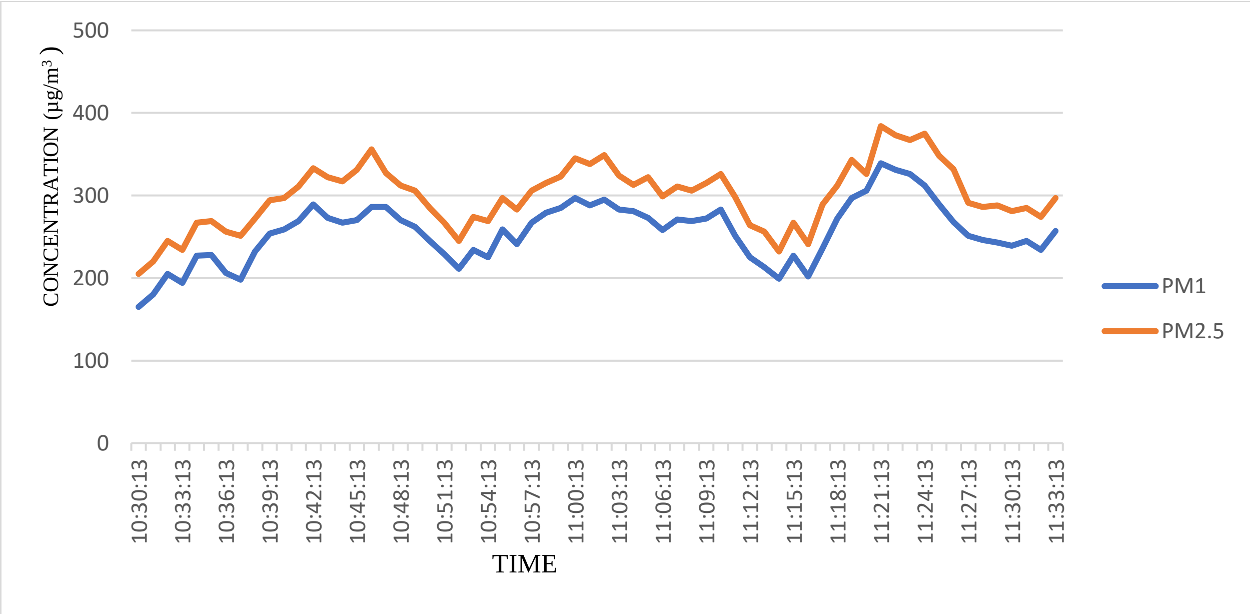


Figure 4.12 Variation of $PM_{2.5}$ and PM_1 concentration during lunch preparation

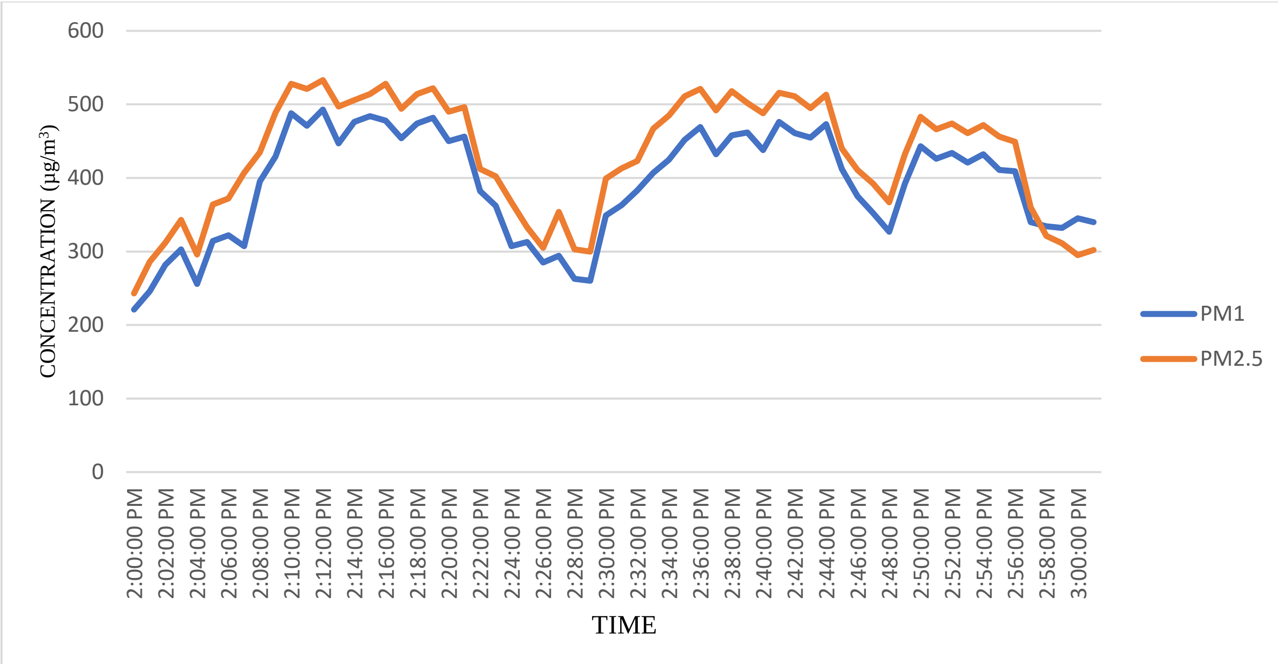


Figure 4.13 Variation of $PM_{2.5}$ and PM_1 concentration during dinner preparation

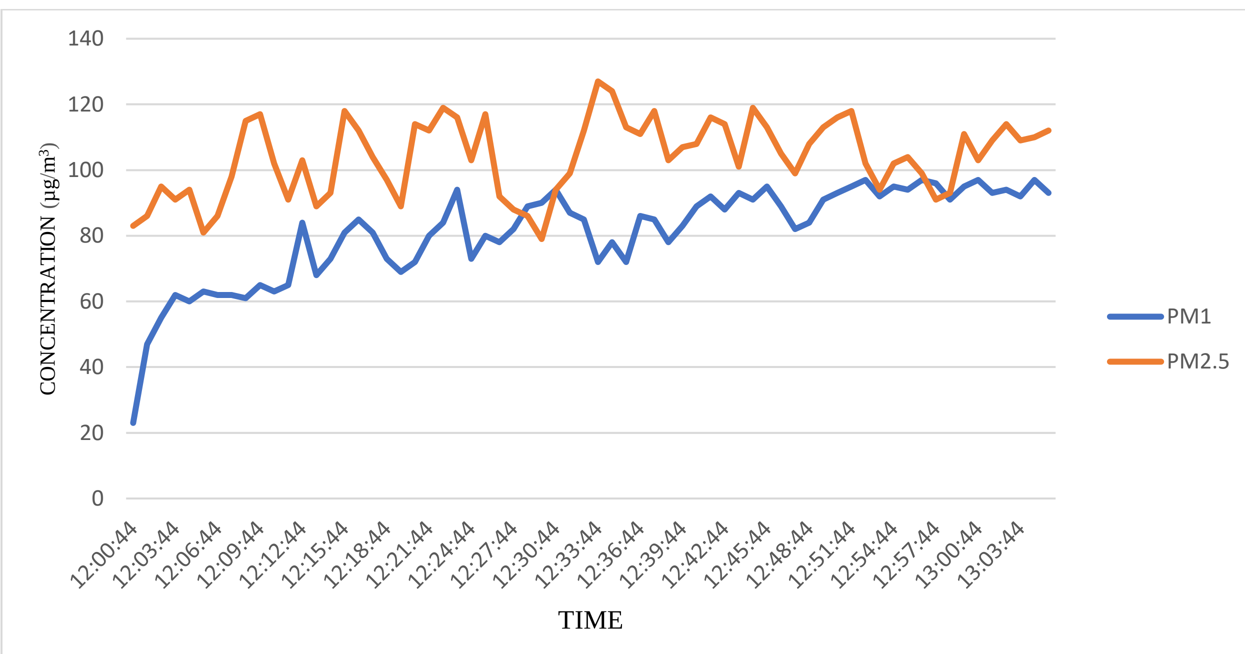


Figure 4.14 Variation of $PM_{2.5}$ and PM_1 concentration in sitting area

4.4 COMPARISION OF TEMPERATURE IN COOKING AREA AND AMBIENT AT DIFFERENT TIME IN DAY

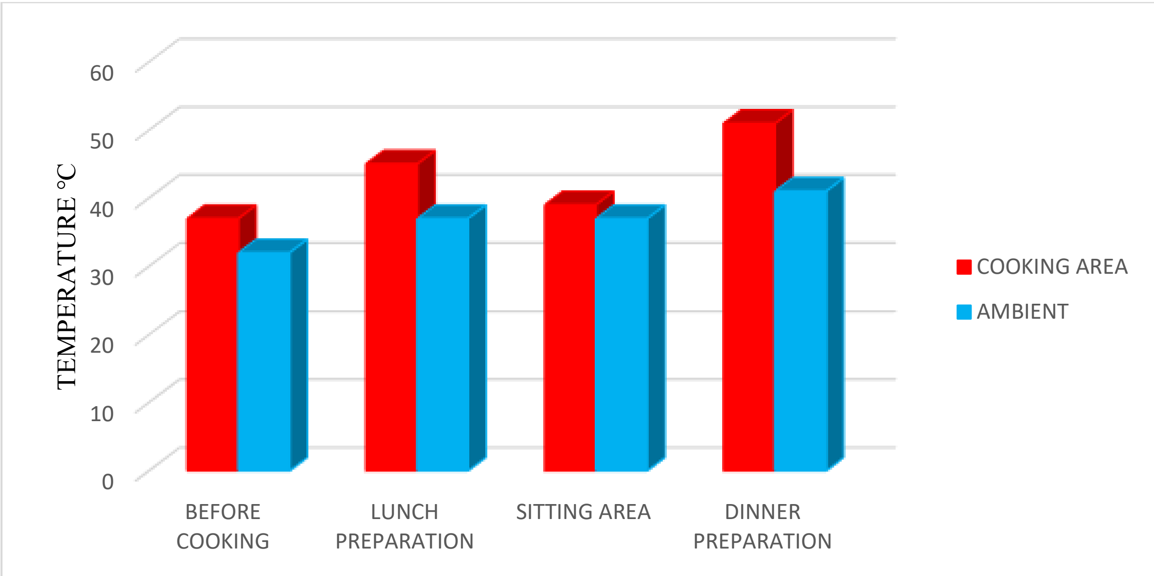


Figure 4.15 Variation in temperature values in cooking area and ambient

Temperature is one of the basic Indoor Air Quality measurements that has a direct impact on the concentration levels of particulate matter and perceived comfort and, in turn, concentration and productivity. Whenever the sampling was done in cooking area for the study, temperature reading was noted inside the cooking area and were compared with the ambient temperature available online on weather forecasting by Indian Meteorological Department.

The results show the difference of 11℃ between the cooking area and ambient area temperature during dinner preparation. due to the less ventilation available in cooking area there was no escape for heat to the ambient atmosphere.

The study was performed in a small hostel canteen, in commercial cooking sector larger difference in temperature could be existing because number of burners running together will increase, number of cooks will increase, area might decrease. These all factors will definitely enhance the temperature of cooking area as compared to ambient temperature.

4.5 COMPARISION OF HUMIDITY OF COOKING AREA AND AMBIENT AT DIFFERENT TIME IN DAY

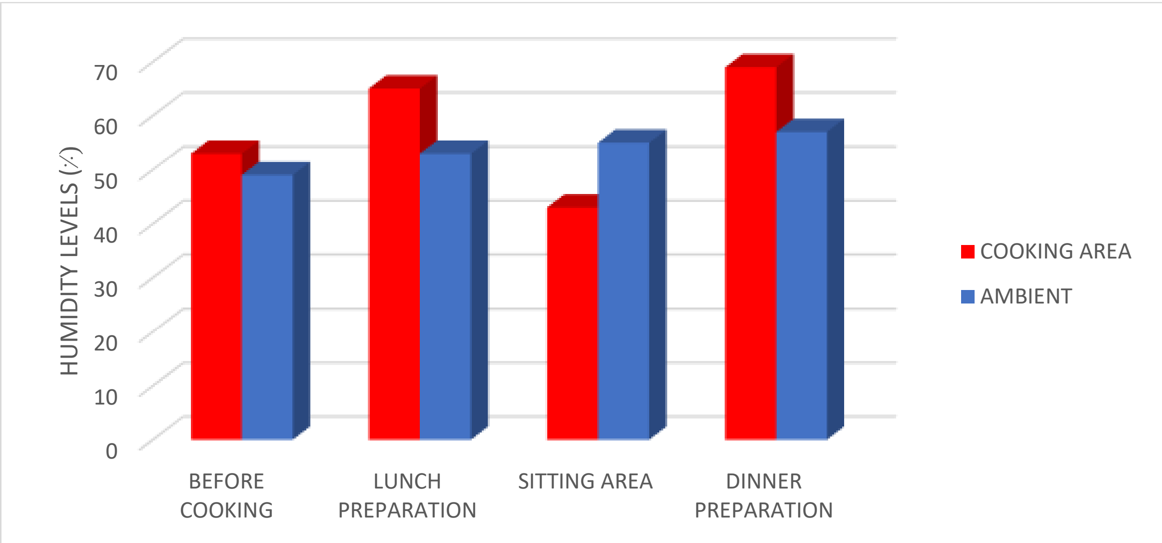


Figure 4.16 Variations in humidity values in cooking area and ambient

Relative Humidity is defined as the mass of water vapor divided by the mass of dry air in the volume in the air at particular temperature. It depends on pressure and temperature of the area where it is calculated.

If the relative humidity is high, it feels more heat and sweats lesser. If the relative humidity is low, it feels much cool than the actual temperature as sweat evaporates quickly. Humidity values less than 20 percent in the winter and greater than 60 percent in the summer on moisture sensor makes feel uncomfortable. Elevated relative humidity leads to the accumulation of particulate matter at the source area.

Relative humidity is measured by equipment called RH meter which consists of inbuilt sensor i.e. moisture sensor in it. It gives an instant value with temperature and humidity measurement.

CHAPTER 5

CONCLUSIONS

The study was undertaken to assess the indoor air quality for commercial cooking sector taking particulate matter ($PM_{2.5}$ and PM_1), temperature and humidity as parameters. To represent the commercial cooking sector study was conducted in hostel canteen where the food was prepared for 800 students which includes morning breakfast, lunch, evening snacks and dinner at night. Air samples were taken with EPAM-5000 (Haze Dust Sampler). The samples were taken from cooking area of canteen before cooking to measure the concentration levels of particulate matter that was present due to previous day cooking. Concentration levels were measured in cooking area during lunch and dinner preparation. Also, the samples were taken in sitting area to measure the concentration levels.

Each time during sampling the value of temperature was noted with the help of thermometers. The value of humidity inside cooking area was noted down with help of RH-meter. Simultaneously the value of ambient temperature and humidity at canteen's location were taken by help of online data available on Central Pollution Control Board(CPCB) and Indian Metrological Department(IMD) site.

Conclusions:

The results of the study are discussed in chapter 4**.** Following conclusions are made on the basis of results obtained**:**

The residue average concentration levels of $PM_{2.5}$ found during sampling done in cooking area early morning before start of any cooking were 120.57µg/m3. In these concentration levels, workers were sleeping at night daily unaware of the severe health impacts they were facing due to it. Due to the light weight and small size particulate matter remains in suspension in the area. The air in the space need to be washed off properly for allowing workers to sleep inside.

During the lunch preparations the values of both $PM_{2.5}$ and PM_1 increased due to the rigorous cooking operations carried. Average concentration level of 299.53µg/m3 of $PM_{2.5}$ and 256.625µg/m3 of PM_1 are very high. Cooks working in these concentration levels for hours daily were found to have respiratory problems, continuous coughing, The average concentration levels during dinner preparation were 533µg/m3 for $PM_{2.5}$ and 385.69 µg/m3 for PM_1 which indicates an alarming situation for commercial cooking sector. Working in such environment is detrimental for any human being. The cooking activities like frying/grilling contributes the most to enhance the particulate matter concentration level in the cooking area. Even the significant concentration values of $PM_{2.5}$ and PM_1 were obtained in the sitting area of canteen. This draws attention to the exposure of guests in the commercial cooking sector.

As per the variations seen in the concentration levels during open mixing of food ingredients, it may conclude that the free escape provided for particulate matter to enter in the indoor air is one of the major contributing factors. Another relation may be drawn from ventilation area as the values lowered down as the ventilation was enhanced by the use extra exhaust installed in cooking area. Hence only the fuel used is not responsible for the indoor air pollution from cooking but the cooking area ventilations, number of exhausts and chimneys installed, space available as per number of workers, scale of cooking and type of cooking operation carried plays significant role.

The guidelines established by the authorities for indoor environment are related to gaseous pollutants not to particulate matter except US EPA. No standards are established in India for indoor air quality. In comparison between standards levied by US EPA the results for all sampling were drastically exceeding permissible limits.

The temperature differences obtained in the cooking area during lunch and dinner preparation was critical as the human body can endure only upto a limited level of temperatures. If temperature exceed more than that level, can cause massive distresses and health issues to humans exposed. In extreme temperature conditions, many vital life functions stop, which might lead to heavy respiration or even a cardiac arrest. It might also cause multiple organ failure and damage to sensory organs.

Also, the study was performed on the hostel canteen which is a smaller part of commercial cooking sector. The results are expected to be enhanced to high levels for larger scale processes like in industries and religious places where cooking is done for thousands of people all round the day. The duration of cooking and the amount of food prepared is also much more as compared to hostel canteen so it can be said that the concentration levels will also be more.

Recommendations:

Analyzing the results of the study following recommendations can be made:

- Open mouth vessels used in cooking by LPG can be replaced by the closed containers which will prevent the free escape of emissions in the air of cooking area or the direct exposure of cooks standing close to vessels for lager span of time.
- Sufficient ventilations can be provided by providing the sufficient number of chimneys and exhausts in the cooking area. Moreover, the chimneys inlet plate can be close to the cooking vessels so that least dispersion of particulate matter takes place. Even the exhaust or chimney outlet can be fitted with the cyclonic precipitator to prevent the ambient air pollution.
- Uncontrolled and high temperature values obtained in cooking area can be lowered down by using vessels equipped with temperature controlling system which will ensure the generation of only required amount of heat from source without affecting the cooking process.
- All commercial cooking kitchens must have an equipment that continuously monitor air quality of cooking area and warns on exceeding the limits set. Connection to the emergency high-power exhaust must be done which can wash off the pollutants in seconds.
- Urgent need of establishing the standards for indoor air quality in commercial cooking sector kitchen has arrived as all the above mention prevention and control steps can only be taken on having comparison of pollutants concentration with some standard values.
- It must be ensured that the already set norms related to the construction of buildings to be used for commercial cooking are followed and implemented properly upto the operational phase not just till getting clearance from authorities as it usually happens. Also, the concern authorities must conduct random visits to the commercial cooking kitchens.
- Lastly awareness in the cooks and workers can only protect them from getting exposed to such high levels of indoor air pollution causing severe health impacts to them.

CHAPTER 6

SCOPE OF FUTURE STUDY

6.1 Electricity: An option

The most important reason for the need to shift from LPG to Electricity in commercial cooking sector is that 80% of LPG is imported in India thereby causing a huge drain of wealth that is creating economic pressure on country. Also, the kitchen running on electricity involves closed vessels, temperature-controlled equipment and many others better features.

The Indians are also shifting towards international cuisine which brings with itself induction cooking. Induction cooking is a faster process that would be helpful in case of commercial kitchens where the food is required to be roiled out quickly. With electricity we can go for controlled heat generation unlike in gas stoves where uncontrolled burning takes place, also unnecessary heating the surrounding. One can adjust the cooking heat instantly and with great precision. Split rotisseries and Griddle heat up from bottom while in case of ovens the heating takes place from to which is more efficient. Electric equipment is more economical in comparison to gas-based ones.

The cooking area and its surrounding area was found to have high temperature difference as compared to ambient due to uncontrolled heat generation in case of LPG based kitchens. This leads to the increase in electricity bills due to higher use of air conditioning system as ceiling fans cannot be used on a gas burner.

In India, there is a big issue of availability of non-stopped electricity supply and the high charges of installation and usage. For the first problem often, generator is thought to be installed that too of higher capacity, such as a propane-powered emergency generator and hence, it leads to more capital expenditure. The world is shifting towards green electric energy which means electric power will be produced by solar, wind or any other renewable sources.

Green Electricity: Solar energy is free of cost and ensures continuous supply of electricity**.** Area where the commercial cooking is done, work space for cooking involved is large enough. The solar plant consists of solar plates which are strong enough to withstand all-natural forces like wind, rain, etc. Using these plates as the roof, area under which will be used as sitting area and eating. Once the installation cost is recovered the food will be prepared at zero fuel cost. By further doing benefit cost analysis on the setting up of kitchen based on green electricity.

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