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Indoor Air Pollution in Rural Micro Environments

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Indoor Air Pollution (IAP) is the 2nd-largest health risk factor in India, causing an estimated 1.1 million deaths per year (GBD, 2013). The predominant source of IAP in rural India is burning of solid fuels for cooking, and heating activities (Smith et al., 1983). It is estimated that of the 2.8 billion biomass users across the world, India alone is home to more than 0.82 billion people, a majority of which comes from its rural areas (TERI, 2015). Solid fuels in the form of agricultural residue (AR), cow dung cakes (CDC) and fuel wood (FW) are predominantly used as domestic fuels in rural India. Biomass combustion results in emission of pollutants such as particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), formaldehyde (HCHO) and other gaseous pollutants (Lawrence and Taneja, 2005; Raiyani et al., 1993; Smith et al., 1983). Fine and ultrafine particulate matter have greater health consequences due to higher mass concentration levels and presence of toxic substances in its composition (Andreae and Merlet, 2001). Studies revealed that IAP extends its affects ranging from being an acute irritant, reducing vital capacity, causing bronchitis, to being a carcinogen causing leukaemia and lung cancer (Kankaria et al., 2014). In rural settings IAP is mostly dependent upon multiple determinants such as type of fuel used for cooking, varied types of kitchen set ups, structural characteristics of houses, household ventilation, locations of house, premises in different geographical conditions and time spent in cooking (Begum et al., 2009; Balakrishnan et al., 2013). Of the above selection criteria varied kitchen setups was considered for the current study. In this paper, we present the measurements of real-time indoor PM exposures for households of rural southern India. Indoor exposures were measured in three types of housing (Type A- Indoor kitchen without partition, Type B- Indoor kitchen with partition and Type C- Open air kitchen) for twenty five days during the winter season of 2016-2017. PM mass concentrations were monitored using a 32-channel optical particle counter (GRIMM Model 1.109) in the living rooms of the three houses. The sampling height maintained was 1.5 m above the ground level, which is the average human breathing height. Results indicated that the PM exposure levels were very high in the houses with and without partitioned indoor kitchens (Types A and B). The diurnal averaged indoor $PM_{2.5}$ and PM_1 concentrations (PM concentrations ± standard error) were above the human permissible limit in the Type A ($PM_{2.5}$:140±37 and PM_1: 106±21 μg/m^3) and Type B ($PM_{2.5}$:411±65 and PM_1: 252±55 μg/m^3) houses. Whereas in the Type C house the concentrations were lower with the 24 hr averaged $PM_{2.5}$ and PM_1 concentrations of 92.7±15 and 64±10 μg/m^3 respectively. During the cooking periods, the hourly averaged $PM_{2.5}$ (1012.7, 2161.42 and 285.2 μg/m^3) and PM_1 concentrations (790.1, 1230.38 and 175.3 μg/m^3) in Type A, B and C house, respectively were more than one order higher than the diurnal averaged concentrations in all the three types of houses.

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Metrics for Indoor Air Quality

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Over the last 3 decades since Indoor Air Quality (IAQ) has been evolved among scientific communities, different metrics and indices have been used to define IAQ. The most common and frequently used simplest measures were ventilation airflow rates and concentration of CO_2. However, such measures had its own shortcomings for the systems that do not have steady contaminant sources or do not provide a constant airflow rate, such as natural, hybrid, or demand-controlled ventilation. Apart from ventilation airflow measurements, occupants satisfaction and dissatisfaction levels were also used sometimes to define the building condition and further the IAQ.

But, in most recent years, since the technology revolution is pacing on its fast voyage with improved analytical procedures and a number of sensor based technologies/ instruments are available in the market, the debate is going on whether we should still rely on simple metric of IAQ? As of now, there is no clear set of metrics that can be used to assess the overall ventilation performance of a building with regard to its indoor air quality, or used in standards or regulations. Therefore, the worldwide discussions among various forum of IAQ are going on the approaches of IAQ measurements, which should not compromise with the basic needs of human, i.e. high quality of life, good health and optimal physical and mental activity.

The most sensible approaches suggested in such international forums are based on health damage, pollutant exposures and on perceived air quality. Though, these approaches may have limitation of a number of assumptions about the pollutants of concern and occupant scenarios but if planned strategically, could lead to useful metrics for IAQ.

As far as **IAQ in India** is concern, there is still no guidelines and standards exist for IAQ. It is still much unexplored area and or just restricted to some academic masters and PhD researches, a need of integrated monitoring/measurements has been identified in the protocol of IAQ in India developed by CPCB, a regulatory body in India for pollution related issues. According to the integrated protocol, the key parameters that should be measured indoor in different types of buildings depending upon their use i.e. *commercial*, *residential* or *sensitive* (the sensitive buildings are classified as hospitals, schools, and old age homes etc. where sensitive receptors like women, children and old age people are occupants) are Environmental measurements (**Biological exposure**: Allergens or microbiological; **chemical exposure**: Dust, aerosols or vapors; **physical exposure**: Acoustic environment, humidity, air movement, thermal environment); Building and ventilation characterization and the time activity assessment and Occupant's health assessment. The need has also been felt for investigation on relations between symptoms and *measured* exposures to multiple specific pollutants. Furthermore, quantitative information is needed on exposure-health response relationships for specific pollutants suspected to cause health symptoms, in order to provide a sound basis for setting standards and for insuring cost-effective mitigation measures. In addition, A framework for understanding how indoor and outdoor sources of pollution together with the ventilation affect the IAQ in buildings is one of the essential parameter considered in IAQ protocol.

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Indoor Environmental Chamber

Dr. Mukesh Khare

Effect of air pollutants on cultural heritage buildings has been an emerging issue in the recent years. Conducting field tests to investigate their same has many social, economic and technical constraints. Alternatively, the environmental chambers can easily help us to serve the purpose of testing the construction materials under variable meteorological conditions and identify reasons to take necessary actions. The environmental chambers are very useful in estimating the effects of air pollutants on building materials. The features of the chamber are

- Speed regulating mechanism
- Uniform flow designed by perforation plates
- Velocity magitudes inside the chamber modelled using COMSOL
- Sample placing assembly
- Concentration monitoring
- Temperature monitoring
- Humidity control and monitoring
- Annular design for achieving streamlined flow

Environmental chambers are extremely useful in developing source emission factors, which can be used in developing indoor air quality models. However, the results have to be validated by performing full scale testing in large chambers for more accurate results. The facility is currently being used at Indian Institute of technology Delhi to investigate the effect of VOC's on the materials. The testing of the materials like marble and redstone are also been considered. Since the facility can simulate the effect of variations in environmental parameters, it can be extensively used in testing the long term effect of the pollutants on the building materials which has archaeological importance.

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Indoor Air Quality Assessment of Different Microenvironments in IIT Roorkee Campus

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The indoor air quality (IAQ) in different dwellings units such as homes, offices, schools, colleges, libraries, public buildings, health care centers or other public/private buildings where people spend significant portion of their time collectively throughout the day is an vital determinant of people's health. Poor IAQ also increases cases of sick building syndrome, respiratory illnesses and losses in productivity and work performances. Poor IAQ in different microenvironment is due to inappropriate urban building designs and indoor pollutant sources, e.g., building materials, furniture, cleaning products and indoor human activities such as cooking, smoking, heating and resuspension of house settled dust. Not only this, ambient air quality (AAQ) also affects the IAQ via infiltration/penetration through windows, doors, ventilation and openings/cracks within the buildings.

At present, if we compare the quantum of research work and publications related to ambient air environment and indoor air environment, former is greatly dominating and there is huge gap in research activities pertaining to indoor air environment. For example, most of the published literature on Indoor air quality for India has focused on IAP due to the burning of biomass fuels in unvented cook stoves in rural, semi urban areas or in urban slums and on their socio-economic status. Though IAP issues in urban areas are equally important, far less attention has been paid on it. Also, compared to the research reviewed in the developed world, only a few research groups are focusing on studies related to IAQ in Indian urban indoor settings. Within this context, a research group at IIT Roorkee is aiming to carrying out a study to assess the particulate matter (PM) concentrations in different types of indoor environment depending upon their use and type of ventilation. We will also determine indoor-outdoor air quality relationships in selected micro-environments, and assess the influence of ventilation on indoor particle concentrations in selected micro-environments. Efforts would also be made to improve scientific understanding on indoor particle dynamics through Computational Modeling.

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Indoor Air Quality Aspects in Urban Kitchens

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To breathe healthy indoor air is considered a fundamental right by the WHO. This fundamental right is regularly breached in most of the Indian kitchens largely due to lack of awareness regarding indoor air quality (IAQ) among the indoor occupants. However, in today's litigious and educated society, we need to be aware of the health and legal ramifications of an unhealthy indoor environment. Inadequate ventilation substantially increases the pollutant concentration during cooking period. Gas stoves are among the major contributors to indoor NO_2 and sub-micron, ultrafine (<1.0 µm) particle concentrations. Indian cooking involves frequent frying and roasting and generates large amount of inhalable vapors and aerosols. It has been reported that PAH concentration in fumes from hot cooking oil are high and they may represent a serious cancer risk for exposed persons. Studies also indicate that dioxins can be generated during frying and when cooking is done with reactive organic chlorides additives. These pollutants can readily diffuse to other indoor areas, thus affecting the health of the persons not directly exposed to such pollutants.

In a study of urban Indian kitchens average PM_{10} concentration, during frying, has been found to be 4857 µg/m^3, and the corresponding value of PM_1 is 3415 µg/m^3. The ratio of PM_1 to $PM_{2.5}$ is 0.75 and the ratio of $PM_{2.5}$ to PM_{10} is 0.94. This clearly indicates that during deep frying, a majority of particles emitted are in the fine range. Further, because these particles are released during use of oil they can have significant impacts on respiratory symptoms of exposed persons. Emission and accumulation of such high particle concentration for significant duration is a cause of great concern. The Maximum average concentration of NO_x is recorded as 309±251.3 µg/m^3. The concentration of pollutants has been observed to vary widely with type of ventilation, habits of using forced ventilation (used throughout the cooking activity or only when there is visible buildup of pollutants), efficiency/capacity of the ventilation, placement of the stove/burners with respect to the ventilation system provided. When the emissions are very high due to large quantity of food being cooked (in hostels, or during festivals) all the PM fractions accumulate if ventilation is only provided by the chimney. This may be due to relatively lower AER provided by chimneys as compared to those by exhaust fans, which may also result in accumulation of gaseous pollutants. Continuous operation of exhaust fan during entire period of cooking significantly affects removal of NO_x.

Domestic cooking thus is an important source of IAP and is associated with significant morbidity and mortality. Health effects of prolonged exposure to combustion generated pollutants primarily depend on type of fuel and stove used, ventilation provisions, cooking practices, duration of exposure, toxicology of pollutant and susceptibility of individual. Considering the plausible toxicity effect associated with these fine particles, it is very important to gain more understanding of the concentration level in residential kitchens.

Indoor Air Quality (IAQ) in Slums

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With the rise in urbanization and the excessive movement of population from rural to urban areas, the metro cities have swollen up beyond their natural boundaries. This eventually results in less per square feet space per person than, is actually required. Poverty increases the burden on the inhabitation forcing more people to live in cramped places. In India, the situation becomes more severe with variations in temperature and humidity levels, lack of awareness regarding the benefits of proper ventilation and use of biomass as a major cooking fuel.

There are very few independent researches happening in the field of Indoor air quality(IAQ) , which has created a major roadblock, in it being recognised as environmental concern. A study done in urban slums in Delhi indicated that the main culprit in increasing the concentration of pollutant indoors was found to be the ignorance of slum dwellers about the need for proper ventilation in their houses. In spite of having windows, they were either closed or stacked with an air cooler which hindered the cross ventilation in the homes. The people living in urban slums had access to cleaner fuels but they opted for tree wood or twigs for cooking as they wanted to increase their money savings. Women and children were found to be more vulnerable to the toxic fumes of biomass fuels as they spent more time indoors and even did the cooking, indoors. The meteorological factors also played an important role in worsening the air indoors during winters, as the occupants exhibited the tendency to keep the doors and windows closed for most part of the day. This practice thereby built up the concentration of indoor air pollutants and its exposure to the slum dwellers resulting in respiratory health problems. An intensive health examination of the women occupants in the slums revealed a decrement in their lung function indices (i.e. FVC and/or FEV1) due to increased concentrations of RSPM and CO_2 indoors during winter months. Respiratory distress symptoms and asthma was found to be prevalent amongst the children living in urban slums.

Certain public health policy implications such as improved stoves with chimneys, use of cleaner fuels like piped compressed natural gas, better housing and kitchen design with improved ventilation will certainly help in controlling indoor air quality amongst the urban poor. Behavioral interventions such as spreading awareness for reducing exposure to smoke, reducing emissions from stove and modified cooking practices would help in reducing the level of pollution indoors.