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Health aspects of Indoor Respirable particulate pollution – The emerging issues

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Abstract
Indoor pollution has become a very important agent affecting the health of people. The type of the reparable particles, their morphology, exposure level and structural features of the indoor environment are all important factors in determining the health effects. The paper-discusses various aspects of indoor respirable particles, characteristics, toxicology, epidemiology and health issues related to them.

Keywords: Indoor air pollution, particulate morphology, aerosols, health hazards

1. Introduction
Fine invisible particles in the urban air, especially those produced by human activities have recently stimulated intense scrutiny, debate, regulation and legal proceedings. The stakes are high, both with respect to health impacts and economical costs, and the methods used previously to resolve similar issues are no longer adequate. Fine Particles (0. 1 to 2. 5 /µm diameter generated from burning of coal, petrol, diesel are a complex mixture of sulphate, nitrate, metals, lead, cadmium, nickel, PAHs etc. It is this cocktail of chemicals which makes these tiny killers lethal. Of primary concern is the fact that finer particles penetrate more readily into cells and through tissue barriers that they have greater surface area per unit mass and a large number of toxic reactions occur at the surface. Years of research have validated the adverse effects of fine and ultra fine particles.

The physical (size, shape etc) and chemical characteristics of respirable particles play a significant role in retention as well as impacts on human respiratory system. The particle size determines the atmospheric half life, fate of the particle in the body and contributes to toxicity. Particles laden with gases like SO_2 & NO_x have higher propensity to harm (PM-NO_x-SO_x synergistics). This paper looks into various aspects of indoor respirable particles: characteristics, toxicology, epidemiology, standards and also health issues related to them.

2. Physical characteristics of fine particles
2.1 Size
The most basic and usually the most easily distinction between particles is their size. The size of the particles provides some information about how it was formed. The usual size range is from 0.01-100 mm aerodynamic diameter. Total suspended particulate matter and suspended particulate matter (TSP and SPM) are the atmospheric aerosols. Aerosols, which originate directly from the sources, are termed as "Primary aerosols". There may be conversion of gaseous matter into the particulate due to many physico-chemical reactions. Such types of particulates are known as "Secondary Aerosols". Fine particles come in many shapes and sizes and from many sources. Not all PM_{10} (Respirable fraction of SPM) is created equal. It can compose of very small particulates of about 0.1 mm to 0.2 mm in diameter and also include particulates at least ten times this size.

2.2 Importance of Size
Smaller the particle, greater the risk. The size of the particles assumes vital importance from the environmental point of view, as that determines how long the particles will remain airborne and also from the point of view of their impact on human health. The size of particles determines how deep they can penetrate our lungs. the synonymous terms used for Size also plays a significant role in inhalabiltiy of the participle. For 10mm particles inhalability is about 77% and for $PM_{2.5}$ the inhalability is more than 90%. Smaller particles which can be high in number but contribute very little to particle mass, have a higher probability of penetration into

the deeper parts of the respiratory tract and can be laden with trace elements and PAH emphasise that particle number emission rate and not particle mass emission rate is of importance for exposure assessment and for developing appropriate control strategies.

2.3 Shape

Morphology relates to the particle shape and the shape features. The concept of aerodynamic diameter does not accommodate the particle shape or the morphological features such as porosity and roughness. These properties are of great significance in characterizing the effect of the particles on the health and the role of the particles in the atmospheric reactions. The shape of the particle (whether spherical, sharp edged, rod like, irregular etc.) also plays a significant role in its retention in the human respiratory system and cardiovascular system. Sharp edged particles can irritate mucous surfaces. Morphology has not been adequately studied.

Many of the recent studies have indicated that the particulates in the accumulation mode are the most critical with respect to human health, visibility and adverse effects caused by acid precipitation. By the number, these particles are the most abundant in the air and most of the mass of the secondary aerosols tends to reside in this range.

3. Chemical characteristics

There is great variation in the chemical composition of the particulates found in the atmosphere and can be homogenous or heterogenous in their structure. Atmospheric particulates contain both organic and Inorganic components. Inorganic components may be derived from both natural or manmade sources. These components when inhaled may cause variety of health effects on human beings and may act as the allergens, mutagens, teratogens or carcinogens. They may also affect the skin, pulmonary membranes, gastro-intestinal tracts and the tissues. They do not degrade like the organic compounds and may accumulate in the body resulting in the chronic symptoms. Potential toxic elements are the arsenic, cadmium, mercury, nickel, lead etc. It is interesting to note that despite such health hazards, the Acceptance Quality Criteria are not yet available for most of these metals. In addition the aerosols may also consist of organic constituents, like PAH, PAN, TOC etc. Most of these species are the results of combustion processes.

3.1 Importance of Chemical Characteristics

The chemical composition of the aerosols affects toxicity, water solubility, hygroscopicity, particle shape and state, acidity related to acid rain and basicity. SO_2 is transformed in the atmosphere to sulphates, thus becoming a component of SPM.

3.2 Health risks of Sulphate Particles

According to WHO, sulphates can be more dangerous than PM_{10} and $PM_{2.5}$ particles. Specifically an increase of 10 mg/m3, of sulphates can cause increase in hospital admission and daily mortality to be as high as 50-60%. Though there is no systematic and regular monitoring of the dangerous trend of 502 converting into sulphate particles in India, preliminary estimates from Delhi based DRDO indicate a positive correlation between SO_2 and sulphates of SPM in Delhi. The World Bank study of 2004 on sour ce apportionment of $PM_{2.5}$ in Delhi shows sulphate levels varied between 5 2 and 19 mg/m3. Sulphates, on an average formed about 10% of $PM_{2.5}$ in Delhi, Mumbai and Kolkata.

3.3 PM Nox Synergistics

A review of literature suggests the possibility of chemical transformation of NO_x to Nitrates (NO_3) which get adsorbed onto the fine particle surfaces. From the health point of view, the synergistic interactions between PM and NO_x Have more deleterious effect on human health than NO_x alone. Increasingly higher correlations between No. And PM nitrates with decreasing particle size (PM10 nitrates & NO_x (0.73), $PM_{2.5}$ nitrates & NO_x (0.87), PM 1 nitrates & NO_x (0.981) have been obtained, reinforcing that combustion generated particulate matter acts as a sink for ambient No. (Sharma *et al*. 2007) [7]. Thus, understanding particulate matter and NO_x interactions is essential in bringing meaningful standards for fine particles and NO_x Especially in view of their synergistic impact on human respiratory system.

4. Toxicology of particulate matter

Toxicology plays several roles in the particulate pollution issue. In reality, health effects are not solely dependent on emissions and concentrations. Rather, they are dependent on doses received by individuals. Doses, in turn, depend on the concentrations in the air actually breathed by people. Over the year s, ambient air quality standards have been set largely on the assumption that fixed monitoring station measurements of air pollution concentrations are representative of exposures people receive. The conventional air quality monitoring data are of little significance when pollutant exposures to women and infants, especially those belonging to lower economic strata, are concerned, for they are often exposed to higher pollutant concentrations and more toxic fumes due to extremely poor indoor air quality. Pollutants released indoors are far more hazardous than those released outdoors because of the close proximity of people and larger exposure time.

Dose-response phenomenon can be investigated to determine at what levels effects occur, and how successfully larger dose modifies responses. Toxicology studies are also needed to identify the mechanism (s) of action that might be involved in the adverse human responses to PM. It is an essential partner to epidemiology in identifying, understanding, and controlling health hazards from chemical substances.

5. Epidemiological studies

Extensive epidemiological studies are required to show how the ambient air pollution affects human health and also to estimate the economic losses due to it. These studies also enable the regulators to know how respiratory problems, cancer and heart disease risks are growing in our cities. The existing NAAQS standards were modified according to the epidemiologic data and because of significant health effects of $PM_{2.5}$, new limits were created for them. The standards were based on two previously invoked averaging times, 24 hours and one year, to protect the public from short term (acute) effects and long term (chronic) effects respectively.

However the status of epidemiological studies in India is very bad. We require more frequent and enhanced studies to estimate the association of PM with public health.

6. Particulate exposure due to combustion of cooking fuels

Many people associate air pollution only with urban outdoor environment, but some of the highest concentrations of pollutants actually occur in rural indoor environment. Indoor pollutants come from burning bio-fuels such as wood, agriculture crop residues and dung cake, which are used extensively by households all over the world. About half the world's population relies on biomass-wood, agricultural residues and char coal as the primary source of domestic energy. Nearly 2 billion kg of biomass is used every day in developing countries. Combustion of bio-fuels in poorly vented kitchens using poorly functioning stoves leads to the release of very high concentrations of suspended particulate matter and noxious gases. (Park *et al*., 2003) [11] Typical pollutant levels during cooking hour s in Indian houses are very high. Even 24-hour levels in many millions of homes apparently exceed those in the worst polluted cities.

The actual exposure levels depend upon several other parameters like, the fuel type, ventilation, and location of kitchen.

In the last decade, a number of quantitative studies of specific diseases contributing to mortality and morbidity have been done in developing countries that for the first time allow estimation of the total burden of disease attributable to use of solid fuels in adult women and young children. High exposure to these pollutants arising from the combustion of bio-fuels has been associated with serious health problems like acute respiratory infections (ARI), chronic obstructive lung disease such as chronic bronchitis and lung cancer, and possibly tuberculosis, adverse pregnancy outcomes, blindness, heart disease and asthma. Efforts have been made to reduce the indoor concentration of pollutants by using better stoves, which require less fuel and generate less smoke. Improved ventilation in the cooking area has also made a difference. Though improved biomass stoves and improving ventilation are likely to be most cost effective options for near and mid term, but in the long term, the option is transition to high quality liquid and gas fuels for cooking. Mixed fuel and kerosene fuel have extremely bad effects on respiratory system in children whose households used these fuels.

Combustion of bio-fuels in poorly vented kitchens using poorly functioning stoves leads to the release of very high concentrations of suspended particulate matter and noxious gases like CO. Exposure to these pollutants has also been shown in several recent studies to be causally linked to sever al health effects especially in women who cook with these fuels and young children.

Ramakrishna tried to establish quantitative estimates of the influence of several environmental and cultural characteristics like stove type, kitchen location, fuel type, etc. on TSP exposures. He found the variable location of kitchen to be statistically significant. Smith reveals that ventilation parameters and stove type influence exposures to women.

An impact of stove and house ventilation conditions on the emission and concentration characteristics of particles was investigated by Morawska *et al*., 2004 [10]. in a study of 15 houses in Brisbane, Australia. They found that frying, grilling, stove use, etc. could elevate indoor sub micrometer particle number concentration levels by more than five times. PM2. 5 concentrations could be up to 3, 30 and 90 times higher than the background levels during smoking, frying and grilling, respectively. This review summarizes the recent shift in research with the emphasis on outdoor to indoor air pollution and emission to exposure and tries to bring out the gaps in the current understanding that would govern the future research on indoor air pollution. Transition to high quality liquid and gas fuels for cooking, improved biomass stoves and improved ventilation have been discussed as steps towards minimizing indoor air pollution from biomass combustion.

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