

# A Review on Association of Air Pollution and Biomass Fumes on Respiratory System

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## ABSTRACT

World Health Organization (WHO) reported that indoor air pollution is one of the ten avoidable risk factors. People believe that air pollution is an outside urban phenomenon, but some of the uppermost concentration occurs in the opposite situation i.e., countryside and in the house. Such levels are due to the high proportion of countryside/less developed countries population relies on unprocessed biomass fuels (like wood, crop residues, dung) which have high pollutant emission factors, in simple small scale burning devices such as household cooking. Domestic cooking is one among the major activities of the rural Indian house wives. Cooking is carried out in an enclosed space with poor ventilation and inefficient stoves. Long duration of exposure to biomass fuel mostly affects women, young girls and children. In most of the developing countries biomass fuel is used for cooking. Girls start cooking at very early age and spend minimum 4-6 hours daily in kitchen for almost 30-40 years which is equivalent to 60,000 hours of exposure. Indoor air pollution occurs primarily by usage of biomass fuels which attributes 1.5-2 million deaths/year.

**Keywords:** Chronic obstructive pulmonary disease, Liquefied petroleum gas, Lungs, Particulate matter

## AIR POLLUTION

Earth's atmosphere is a complex natural gaseous system essential for support of life. Due to rapid urbanisation our earth's ecosystem is under threat. Polluted area (caused due to usage of more and more vehicles), biological materials and other harmful substances released into atmosphere causes damage to food crops, diseases and death in humans [1]. It has become a major problem that is affecting millions of people worldwide. WHO estimated that air pollution is known to cause death of 2.4 million people per year.

Indoor air pollution and urban air quality are listed as two of the world's worst poisonous pollution problems in the 2008 Blacksmith Institute, World's Worst Polluted Places report [2]. There are many causes for air pollution but generally classified as gaseous and particulate pollutants. Gaseous pollutants include Sulphur Dioxide (SO<sub>2</sub>), Nitrogen Oxides (NO<sub>x</sub>), Ozone (O<sub>3</sub>), Carbon Monoxide (CO), Volatile Organic Compounds (VOC), Hydrogen Sulphide (H<sub>2</sub>S), Hydrogen Fluoride (HF), and various gaseous forms of metals which are emitted from fossil fuel, fired power plants, smelters, industrial boilers, petroleum refineries, and manufacturing facilities. This may cause damage to natural resources which ultimately leads injury to ecosystems, organisms and respiratory diseases in human [3,4]. Particulate pollutants come both in large and small/fine forms. Larger ones include dust, asbestos fibres, and lead. Finer ones include sulfates (SO<sub>4</sub>) and nitrates (NO<sub>3</sub>). Main sources of these pollutants are automobile industries, mining operations, power plants, etc. These particulates pollute the air which leads to potential health problems especially to those individuals who work in these industries and who are exposed to dust for a longer time [5]. Particulate pollutants are classified as primary and secondary pollutants. Primary ones are emitted directly into the air from pollution sources. Major primary pollutants produced by human activities include SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub>, CO and VOC. Secondary ones are produced when primary pollutants undergo chemical changes in the atmosphere. Example for secondary pollutant is O<sub>3</sub>. It is formed when NO<sub>2</sub> and VOCs are assorted and warmed by sunlight. O<sub>3</sub> is a major component of smog. O<sub>3</sub> present in the troposphere/atmosphere is close to the ground,

should not be confused with beneficial ozone that is located in the stratosphere/ atmosphere. This beneficial ozone protects the earth from harmful ultraviolet light [6].

**Sources of air pollution:** There are various factors responsible for releasing pollutants into the atmosphere. These sources can be classified into two categories: Anthropogenic/man-made sources and Natural sources. Man made sources are smoke stacks of power plants, waste incineration and biomass used for cooking in developing and poor countries [7]. Natural sources like large areas with few or no vegetation, methane, emitted by the digestion of food by animals e.g., cattle [8].

**Percentage of Population Exposed to Air Pollution:** Air pollution can affect any one, but those who are suffering from lung, heart diseases and old age are more likely to be affected. Pollutants aggravate the symptoms of asthma in old people because of weak immune system [9].

**Health Effects Associated with Exposure to Air Pollution:** Air pollution leads to changes in respiratory and cardiovascular functions, clinical symptoms, outpatient and emergency room visits, hospital admissions and finally premature death. However, the number of people affected worldwide is quite significant. Epidemiological studies using sophisticated statistical tools have shown that risk of air pollution related to health seems to be relatively low. In other words, even when the WHO 2000 air quality guidelines are met, the increased health risk still exists [1,9]. Chronic exposure to air pollution is a significant risk factor for a number of health conditions including respiratory infections, Chronic Obstructive Pulmonary Disease (COPD), stroke and lung cancer. Health effects are difficulty in breathing, wheezing, coughing, asthma and worsening of existing respiratory and cardiac conditions [1].

According to WHO report, indoor air pollution is the 10<sup>th</sup> preventable risk factor. Although many people think of air pollution as an outdoor urban phenomenon, some of the highest concentrations occur in the inverse situation, i.e., rural and indoors. Such levels are due to the high proportion of rural/developed countries population relying on

unprocessed biomass fuels (like wood, charcoal, agricultural waste, crop residues, dung) which have high pollutant emission factors, in simple small scale combustion devices such as household cooking. Research has also shown that there is derangement of respiratory function in women who are exposed to these fumes [1,2].

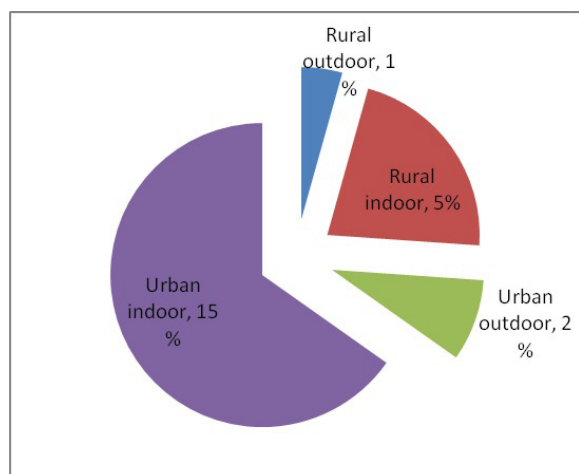
## BIOMASS FUELS

It is a renewable energy source and biological material derived from living, or recently living organisms. It can be often made out of plant matter grown to generate electricity or heat. It can be converted into other types of energy too such as methane gas or fuels used for transportation, such as ethanol or biodiesel fuels.

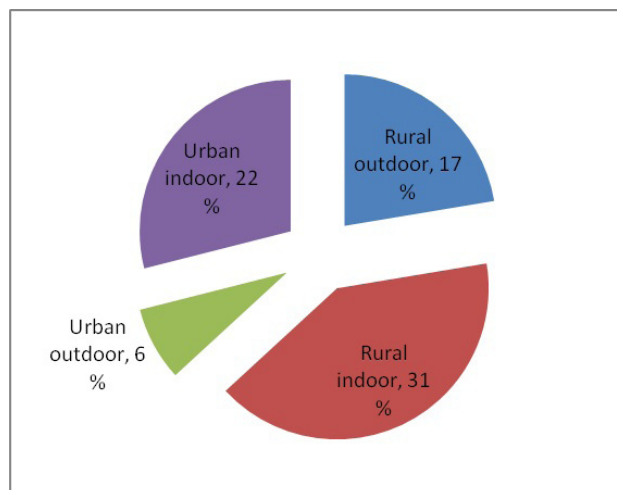
**Purpose of using Biomass and its Effects:** It is the most precious and versatile resource as solar energy in earth crust which provides not only food but also energy, building materials, fabrics, medicines and chemicals. Biomass is used since the discovery of fire for various tasks such as fuel for cooking, automobile, electricity, etc. In India 2.5 billion people rely on biomass for cooking and remaining house hold works in urban and rural areas [10]. Half of the world's population relies on biomass because they are cheap and mostly free of cost when compared to other fuels [11,12]. In the absence of new policies, the number of people relying on biomass will increase to over 2.6 billion by 2015 and to 2.7 billion by 2030 due to increased cost of other fuels. Biomass fumes cause air pollution which leads to death of 1.3 million people yearly, mostly women and premature children [10,13]. Studies show that concentrations of ambient air particles are associated with a wide range of effects on human health, especially on cardio respiratory system [14]. Growing evidence indicates that particulate pollution increases daily deaths and hospital admissions throughout the world [15].

## HISTORICAL PROSPECTIVE

From the 1960s through 1980s, several population based studies were taken up in the industrialized countries and these investigations confirmed the adverse effects of air pollution on human health. These findings opened a floodgate of epidemiological and toxicological investigation on fine and ultrafine particulate biomass pollution and their effect on the respiratory diseases. It was found that long-term, repeated exposures to biomass pollution increase the cumulative risk of chronic pulmonary and cardiovascular disease and even death [16]. WHO estimated that urban air pollution is responsible for approximately 800,000 deaths and 4.6 millions lost life-years. The estimated health impact of urban air pollution is based largely on the results of epidemiological studies conducted in industrialized countries. [Table/Fig-1,2] shows that indoor air pollution by biomass fumes account for 76% in developing countries and it accounts for 23% in developed countries [17].



**[Table/Fig-1]:** Air pollution caused by biomass fumes in developed countries. Source: Krik R. Smith Fuel combustion, air pollution. Exposure and health: situation in developing countries [17].



**[Table/Fig-2]:** Air pollution caused by biomass fumes in developing countries. Source: Krik R. Smith Fuel combustion, air pollution. Exposure and health: situation in developing countries [17].

**Biomass Fumes Pollution and Respiratory System:** Air borne pollutants enter the body through breathing, causing damage to primary target lung apparatus such as bronchi, bronchioles and alveoli. Studies show that about 480 million alveoli are present in both lobes of an adult human lung; women will be having less alveoli and lung volume than men [18]. The mean size of single alveolus is  $4.2 \times 10 \mu\text{m}^3$ . Alveoli make up approximately 64% of the lung space. Human lungs have a total surface area of 1,400  $\text{m}^2$ , and every day we inhale approximately  $15\text{m}^3$  of air. Weight of this inhaled air is greater than the food and water we consume in a day. The lung volume and breathing frequencies of healthy adults at rest is 400-500ml and 15-17 breaths per minute respectively [19].

The pollutants present in biomass fumes include  $\text{CO}$ ,  $\text{SO}_2$ ,  $\text{NO}$ , suspended particulate matter, benzene and benzopyrene [14].

## POLLUTANTS

**The pollutants present in biomass fumes include:**

**Carbon Monoxide (CO):** It is a toxic gas emitted into the atmosphere as a result of burning process formed by the oxidation of hydrocarbons and other organic compounds. The CO gas at 1000rpm (release per minute) can cause unconsciousness in about one hour and death in four hours. However, concentration of CO as little as 200 rpm may produce symptoms of poisoning. If inhaled for few hours it may be toxic, given at concentration of 30 rpm as it causes dizziness, headache [20]. CO interferes with  $\text{O}_2$  transport through the formation of carboxyhemoglobin. Intense short term exposure to CO can lead to loss of consciousness was known by physicians in the late 19<sup>th</sup> century. It can be used as an anaesthetic [21].

**Sulphur Dioxide (SO<sub>2</sub>):** It is an acidic gas emitted indirectly proportional to the amount of sulphur in fuel. It combines with water vapour in the atmosphere to produce acid rain. It can affect human health more likely in those suffering from asthma and chronic lung diseases. Evidence suggests that exposure to  $\text{SO}_2$  given at low levels makes the airways in the lung more sensitive to bronchoconstrictors, substances that cause airways to constrict. This in turn inhibits  $\text{O}_2$  exchange and results in wheezing, gasping, shortness of breath. The relative risk of respiratory mortalities increase in the concentration of pollutant ranged from  $1.015\text{mg}/\text{m}^3$  to  $10\text{mg}/\text{m}^3$  [22].

**Nitrogen Monoxide (NO):** NO is formed during combustion process at high temperatures from the oxidation of nitrogen in air. The major types of oxides of nitrogen present in air are NO and  $\text{NO}_2$ . The main source of NO is road traffic and biomass emissions. Major amount of NO is emitted by biomass [23].  $\text{NO}_2$  is a precursor of O<sub>3</sub> formed in the troposphere. Oxides of nitrogen are immunotoxic and increase the susceptibility of respiratory tract to infections such as

influenza. Frequent exposure to high concentration of NO causes airway irritation and consequent acute respiratory illness [23].

**Suspended Particulate Matter:** Particulate Matter (PM) is combination of solid particles and liquid droplets also known as aerosols found in the air. Coarse particles/ $>2.5\mu\text{m}$  in diameter come from windblown dust and grinding operation is also known as PM10. Fine particles/ $<2.5\mu\text{m}$  in diameter of PM 2.5 are emitted from burning of timber, which causes health problems comprising of premature death, respiratory related hospital admission and emergency room visit. The exacerbation of asthma, acute respiratory symptoms such as severe chest pain, gasping, coughing, chronic bronchitis and decreased lung function. Persistent exposure to biomass smoke is associated with impaired lung function, COPD, sore throat, cough, recurring head ache, eye irritation, dizziness, muscle pain, asthma, life threatening health problems and associated with greater risk of hypertension, cancer in lungs. Women who were using biomass fuel had several cellular changes in their lungs. Sputum samples of these women contained an excess of alveolar macrophages, neutrophils, eosinophil's, lymphocytes [17,22].

**Effect of Chronic Exposure to Pollutants Present in Biomass Fumes:** The symptoms are broadly classified into 2 groups: Upper Respiratory Symptoms includes-Runny nose, Sinusitis, Sore throat, Wet cough, dry cough, cold, head ache, red eyes and fever. Lower Respiratory Symptoms includes-wheezing, phlegm, chest discomfort and shortness of breath. The structural and functional damage of respiratory system, very often the symptom of multifactor respiratory diseases like asthma and COPD are aggravated following exposure to biomass fumes pollutants [24].

#### **Adverse Health Effects of Biomass Fumes Pollution:**

**Overall Mortality:** There is a little doubt that exposure to biomass emissions result in increased risks of mortality, particularly from cardiopulmonary causes. A meta analysis found that PM10, CO, NO<sub>2</sub>, O<sub>3</sub> and SO<sub>2</sub> were significantly associated with mortality. A study in Los Angeles for the period 1982-2000 found a strong increase in mortality with prolonged exposure to PM2.5. Among all of them NO<sub>2</sub> was the strongest predictor for mortality. This effect was again evident during a later on analysis of 12 Canadian cities between 1981-1999 were positive and statistically significant association was observed between variations in NO<sub>2</sub> concentration and fluctuation in daily mortality rates [25].

**Respiratory Effects:** One of the most commonly studied and reported health effect linked to pollution was respiratory morbidity. Sood A have found that exposure of biomass leads to adverse effects on respiratory system ranging from coughing and wheezing which are acute symptoms, chronic conditions such as asthma, CB and emphysema [26]. Studies have shown varying results on the relationship between NO<sub>2</sub> exposures on respiratory health. NO<sub>2</sub> is most clearly associated with cough [15].

The decrease in lung function in biomass fuel users may be due to the chronic inhalation of particulate matter and toxic gases emitted during biomass combustion leading to inflammatory changes. It can be explained as if when cooking index is increased, the pulmonary functions are also much affected. Cooking index indicates number of hours of cooking per day is multiplied with number of years of cooking [27].

**Cooking index = No. of hours of cooking/day × No. of years of exposure [27].**

#### **Previous Studies Associated with Biomass Fuels and Lung Function Tests:**

Revathi M et al., found that the lung function parameters were significantly lesser in the study group, exposed to biomass fuel and concluded that the reduction in the pulmonary function in the biomass exposed women could be due to high exposure of biomass pollutants with inadequate ventilation [28]. Agarwal A et al., found that there is impairment of the lung function in women exposed

to biomass fumes compared to those not exposed to such fumes [29]. Reddy TS et al., indicated that passive smoking showed no significant difference between the two groups using biomass and LPG and may be due to better ventilation in kitchens [30]. Levi M et al., studied pulmonary function tests in COPD patients and results were compared with the controls and found that wood or charcoal alone independently increased the risk of COPD and concluded that a strong association between wood or charcoal smoke exposure for COPD [31].

Behera D et al., studied ventilatory function in non-smoking rural Indian women using different cooking fuels. Lung function parameters were measured in 3,318 non smoking Indian women using four different types of cooking fuels (biomass, LPG, kerosene and mixed). Biomass fuel users had FVC values less than 75% predicted whereas in other groups it was more than 75% predicted. However, FEV1, FEV1/FVC (%) and PEFr were within normal limits in all the four groups. The absolute values of all the three parameters of lung functions were the lowest in the biomass and mixed fuel users. A negative correlation was observed between these parameters and the duration of cooking and exposure index and showed that, lung function, particularly FVC, is affected by indoor air pollution due to domestic biomass cooking fuel [32].

Pravallika P et al., showed biomass fuel for cooking had sub clinical respiratory impairment mainly in early stage small air way obstruction. The adverse effects of biomass fuel on lung function could be due to exposure to high concentration of pollutants like CO, SO<sub>2</sub>, NO<sub>2</sub>, PM, polyhydroxy aromatic hydrocarbons liberated by biomass fuel combustion and inadequate ventilation. It is also found that degree of dysfunction or lung impairment correlates with duration of exposure [24].

Kiraz K et al., compared frequency of COPD and CB in rural women exposed to biomass fuels and urban women who are not exposed to such fuels and stated that all the pulmonary functions tests were normal except FEV which lowered in rural women leading to COPD [33].

Po JYT et al., concluded that exposure of biomass leads to adverse effects on respiratory system among rural population. Awareness and remedial measures like improvement of stove design lowers exposure to emission which might reduce adverse effects [34].

Rinne ST et al., showed that there was a significant increase in mortality of infants ( $p=0.008$ ), increase in history of cough ( $p=0.02$ ) and ear ache ( $p<0.001$ ) in children among families using higher proportion of biomass fuel for cooking [35].

Lahari T et al., studied health impact of biomass fuel use in rural India and showed respiratory symptoms like cough, sore throat, wheeze and chest pain were more prevalent in women using biomass fuels, and lung functions were impaired in biomass users. Sputum cytology of a large majority of biomass users revealed inflammatory and hypersensitivity reactions, and their blood samples showed anaemia, low antioxidant levels, depletion of CD4+ T helper cells and significant increase in CD8+cytotoxic T cells and CD56+ natural killer cells, indicating altered immunity. Biomass users had thrombocytosis, platelet P-selectin overexpression and increased micronucleus frequency in exposed cells, suggesting greater risk for cardiovascular problems and genotoxicity [36].

Liu S et al., studied the association between COPD and the use of biomass fuels for cooking and heating in developing countries and showed that the prevalence of COPD is significantly higher in rural population. They concluded that indoor pollutants from biomass fuels was an important risk factor for COPD [37].

## **CONCLUSION**

Healthy non smoking women using biomass fuel for cooking are affected by sub clinical respiratory impairment mainly early stage small air-way obstruction. The adverse effects of biomass fuel on lung



function could be due to exposure to high concentration of pollutants like carbon monoxide, sulphur dioxide, nitrogen dioxide, particulate matter, polyhydroxy aromatic hydrocarbons liberated by biomass fuel combustion and inadequate ventilation. It is also found that degree of dysfunction or lung impairment correlates with duration of exposure.

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