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REVIEW ARTICLE

Menace of Air Pollution Worldwide

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ABSTRACT

Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural environment or built environment, into the atmosphere. The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet Earth. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems. These are greater cause for concern because they are inadequately monitored. Air pollution from growing vehicular traffic, cutting down of trees to build express highways and flyovers and the hazards from industrial effluent have sharply increased the incidence of a range of diseases , from asthma to cancer to mental retardation, caused by increasing levels of lead (Pb) in the blood stream. Air pollution has become a devastating child killer throughout Asia. Children living in cities are unintended victims of the rapid industrialization and urbanization of most of Asian countries, poisoned by breathing air polluted by motor vehicle exhausts and industrial smokestacks. But kids in rural areas don't escape harm either. Children die every year from breathing smoke from fires that turn their own homes into death traps. Because diseases tied to environmental factors can have more than one cause, it's impossible to state flatly how many children are victims of air pollution. The large proportion of time that most people spend inside air-conditioned spaces increases the likelihood that poor indoor quality may cause adverse reactions such as allergies, eye irritation, headaches, feeling of confusion, and drowsiness as well as more serious long term effects. Carbon dioxide levels can be used as an indicator to evaluate whether adequate ventilation is taking place in the building. A high concentration of CO_2 may indicate that other contaminants in the building may be concentrating. Problems associated with high CO_2 are drowsiness, fatigue, and sick building syndrome. Environmental tobacco smoke (ETS) is the major sources of indoor air contamination. Inhalation of ETS is commonly termed as "second hand smoking" or "passive smoking". The ubiquitous nature of ETS in indoor environment indicates that some unintentional inhalation of ETS by non-smokers is inevitable. ETS is a dynamic and complex mixture of more than 4000 chemicals found in both vapour and particle phase. Air pollution is usually concentrated in densely populated metropolitan areas, especially in developing countries where environmental regulations are relatively lax or nonexistent. However, even populated areas in developed countries attain unhealthy levels of pollution. This manuscript delineates about various air pollutants, related health hazards and control measures.

KEYWORDS: *Carbon Monoxide; Polycyclic organic matter; Environmental Performance Index; COPD: VOCs; SPM; Health hazards; POPs' PAN; PAH*

INTRODUCTION

Air around us is toxic, full of toxins that cause cancers, along with other serious ailments. The magnitude of toxics is alarming, especially those emitted by vehicles. These are greater cause for concern because they are inadequately monitored. A recent study, Smoke Screen: Ambient Air quality In India, by the Community Environmental Monitoring (CEM), a Chennai-based people's movement, reported that air toxics in ambient air, on an average, exceed the US Environmental Protection Agency (EPA) Region 6 screening levels by a factor of 1,174-32,000. Screening levels, calculated for residential exposure, are based on a one-in-a-million cancer risk or a 'hazard quotient' of one for non cancer effects. We normally associate conventional pollutants like particulate matter (PM), Oxide of nitrogen (NOx), hydrocarbons and Carbon Monoxide (CO) with vehicles. But

Benzene, acetaldehyde (CH_3CHO), 1,3-butadiene, polycyclic aromatic hydrocarbons (PAHs), and formaldehyde (HCHO)are among the other pollutants that also emanate from vehicles and are classified as mobile source air toxics by USEPA. [Poisonous mobile matter: Acetaldehyde, Acrolein, Arsenic compounds, Benzene, 1,3 butadiene, Cr-compounds, Dioxin/Furans, ethylbenzene, Formaldehyde, n-Hexane, Lead compounds, Mn-compounds, Hg-compounds, Diesel particulate matter 7 Diesel exhaust organic gases, Naphthalene, Ni-compounds, Polycyclic organic matter, styrene, Toluene, Xylene, they are emitted from a variety of sources but with the ever-growing number of vehicles on road, there needs to be an increasing check on such toxics. A greatest risk from both indoor and outdoor air pollution, are children under five years of age. Numerous studies over the last 7 years, including a major one released last year by the University of Southern California (USC), have demonstrated that when it comes to air pollution, children are not merely small adults. At the rout of the outer air pollution problem is the enormous resent growth in region. In the past 20 years, the gross domestic product (GDP) of South Korea has risen 7 fold and China's by almost as much. It has quadrupled in Thailand and increased 5 fold in Hong Kong. Even India's GDP has more than tripled. There are now more than 10 million cars and jeeps in the country, and every year this figure is going up by at least a million. Several of the world's most polluted cities are in India.

India ranks 123rd in the 2010 Environmental Performance Index (EPI) while Iceland leads the world in addressing pollution control and natural resource management challenges, the latest index has revealed. Of the newly industrialized nations, China and India rank 121st and 123rd, respectively, reflecting the strain rapid economic growth imposes on the environment, stated the report released at the World Economic Forum Annual Meeting 2010. However, Brazil and Russia rank 62nd and 69th, suggesting that the level of development is just one of many factors affecting placement in the rankings. The index is produced by a team of environmental experts at Yale University (YU) and Columbia University (CU). This is the third edition of the EPI, which has been revisited biannually since 2006. The EPI ranks 163 countries on their performance across 25 metrics aggregated into ten categories including: environmental health, air quality, water resource management, biodiversity and habitat, forestry, fisheries, agriculture, and climate change. The US is ranked 61st, with strong results on some issues such as provision of safe drinking water and forest sustainability, and weak performance on other issues including GHG emissions and several aspects of local air pollution. The ranking puts the US significantly behind other industrialized nations like the Britain (14th), Germany (17th) and Japan (20th). Over 20 members of the European Union outrank the United States. The United States' ranking does not reflect policy activities of the Obama Administration, as the 2010 EPI builds on data from before 2009. Iceland's top-notch performance derives from its high scores on environmental public health, controlling GHG emissions and reforestation. Other top performers include Switzerland, Costa Rica, Sweden and Norway – all of which have made substantial investments in environmental infrastructure, pollution control and policies designed to move toward long-term sustainability.

INDOOR AIR POLLUTION

In many people's minds air pollution is associated with the contamination of urban air from automobile exhausts and industrial effluents. However, in developing countries, the problem of indoor air pollution far outweighs the ambient air pollution. There are four principal sources of pollutants of indoor air: (i) combustion, (ii) building material, (iii) the ground under the building, and (iv) bioaerosols. In developed countries the most important indoor air pollutants are radon, asbestos, volatile organic compounds, pesticides, heavy metals, animal dander, mites, moulds and environmental tobacco smoke. However, in developing countries the most important indoor air pollutants are the combustion products of unprocessed solid biomass fuels used by the poor urban and rural folk for cooking and heating. Approximately half the world's population and up to 90% of rural households in developing countries still rely on unprocessed biomass fuels such as wood, dung and crop residues. A recent report of the World Health Organization (WHO) asserts the rule of 1000 which states that a pollutant released indoors is one thousand times more likely to reach people's lung than a pollutant released outdoors. It has been estimated that about half a million women and children die each year from indoor air pollution in India. Compared to other countries, India has among the largest burden of disease due to the use of dirty household fuels and 28% of all deaths due to indoor air pollution in developing countries occur in India. The type of fuels used by a household is determined mainly by its economic status. In the energy ladder, biomass fuels namely animal dung, crop residues and wood, which are the dirtiest fuels, lie at the bottom and are used mostly by very poor people. Electricity, which is the most expensive, lies at the top of ladder and it is also the cleanest fuel.

The 1991 National Census for the first time inquired about the fuel used for coking. It revealed that about 90% of the rural population relied upon the biomass fuels like animal dung, crop residues and wood. A small portion used coal. Nation-wide about 78% of the population relied upon the biomass fuels and 3% on coal.

MAJOR AIR POLLUTANTS RELEASED FROM BIOMASS COMBUSTION

It has been estimated that more than half world's households cook their food on the unprocessed solid fuels that typically release at least 50 times more noxious pollutants than gas. The stoves or chullah used for cooking are not energy efficient. The fuels re not burned completely. The incomplete combustion of biomass releases complex mixture of organic compounds, which include suspended particulate matter, carbon monoxide, poly organic material (POM), poly aromatic hydrocarbons (PAH), formaldehyde, etc. The biomass may also contain intrinsic contaminants such as sulphur, trace metals, etc.

Particulates

In recent years a large number of studies of health impact of suspended particulate air pollution have been undertaken in developing countries. These studies show remarkable consistency in the relationship observed between changes in daily ambient suspended particulate levels and changes in mortality. Smith8 estimated the health risk from exposure to particulate air pollution by applying the mean risk per unit ambient concentrations based on the results of some urban epidemiological studies. The range of risk was found to be 1.2 - 4.4% increased mortality per 10 mg/m^3 incremental increase in concentration of respirable suspended particles (PM). For the calculations of estimates, it was assumed that the health risk has linear relationship to exposure, the risk factors determined for urban centers of developed nations were used as standards; where the PM data were not available, 50% of suspended particulate matter (SPM) levels were considered as equivalent. The above assumptions may add to inaccuracy already inherent in such estimates.

Carbon Monoxide

Incomplete combustion of fuels produces carbon monoxide (CO). The CO and particle emission pose a serious problem when biomass fuels are used. Smith has estimated that about 38, 17, 5 and 2 g/meal carbon monoxide is released during the household cooking, using dung, crop residues, wood and kerosene respectively. During the use of liquid petroleum gas (LPG) a negligible amount of CO is released. A study by the National Institute of Occupational Health (NIOH), Ahmedabad reported indoor air CO levels of 144, 156, 94, 108 and 14 mg/m^3 air during cooking by dung, wood, coal, kerosene and LPG respectively. The short-term health effects of CO exposure are dizziness, headache, nausea, feeling of weakness, etc. The association between long-term exposure to carbon monoxide from cigarette smoke and heart disease and foetal development has been described by several authors.

Poly Organic Material and Poly Aromatic Hydrocarbons

Poly organic material is a loose term used to depict a group of chemicals having two or more rings. Of several chemicals included in this group, the PAHs have attracted interest for their possible carcinogenic effects. In addition to PAH, azo and arino compounds have also been found to be potentially carcinogenic. Most other categories of POM are of less environmental interest or are not found in large amounts in organic combustion products. Polycyclic aromatic hydrocarbons constitute a large class of compounds released during the incomplete combustion or pyrolysis of organic matter. They are often called polynuclear aromatic (PNA) because they contain three or more aromatic rings that share carbon atoms. Benzo(a)pyrene (BaP) is one of the most important carcinogen of the group. Often it is measured to indicate the presence or absence of PAHs although the relationship between BaP content and actual carcinogenicity may be weak. Anthracene and phenanthracene are not carcinogens but methyl additions may render them carcinogenic. PAHs are activated by the hepatic microsomal enzyme system to carcinogenic forms that bind covalently to DNA. Study by NIOH showed that the indoor levels of PAH (total) during use of dung, wood, coal, kerosene and LPG were 3.56, 2.01, 0.55, 0.23 and 0.13 μg/m^3 of air respectively. These PAH were fluorene, pyrene, chrysene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(ah) anthracene, benzo(ghi)perylene and indeno(1,2,3-cd) pyrene. All these PAHs except the first three have been classified as possible carcinogens.

Formaldehyde

Formaldehyde levels were measured in indoor environment during cooking by different fuels. The formaldehyde mean levels were 670, 652, 109, 112 and 68 µg/m^3 of air for cattle dung, wood, coal, kerosene and LPG respectively. The formaldehyde is well recognized to be an acute irritant and long-term exposure can cause a reduction in vital capacity and chronic bronchitis. The formaldehyde is well known to form crosslinks with biologic macro-molecules. Inhaled formaldehyde forms DNA and DNA-protein cross-links in the nasal respiratory mucosa. The formaldehyde has been shown to be carcinogenic in a dose dependent fashion in rodents. The studies done in workers occupationally exposed to formaldehyde have consistently (11 of 13studies reviewed) shown higher incidence of leukaemia. In an epidemiological study in U.K., significantly excess mortality from lung cancer was observed in workers exposed to high levels of formaldehyde.

Mutagenic Activity of the Smoke Particulate Extract

Microbial tests are widely used as a screening tool for assessing mutagenic potential of chemical substances. The particulate matter in the smoke generated as a result of incomplete combustion of biomass fuels contains a number of organic compounds. To evaluate their carcinogenic potential, it is necessary to screen their mutagenicity through simple and rapid microbial assay as a first step. Ames assay is simple and sensitive enough to measure mutagenicity of air-borne particulates, so that many researchers have applied this assay to demonstrate the ambient carcinogenic and mutagenic compounds in the extractable organic matter from air-borne particulates. Mutagenic response of complex mixtures of polycyclic organic matter from the combustion of biomass energy fuels was studied using tester strains TA 98 and TA 100 of Salmonella typhimurium which can detect the presence of frame-shift and base-pair mutagens. The results indicated that the organic residues of smoke particulates of wood and cattle dung fuels contained direct acting frameshift mutagens and cattle dung contained only direct acting base-pair mutagens while indirect acting frame-shift and base-pair mutagens were found to present in smoke particulates of both the energy fuels.

SPECIFIC DISEASES ASSOCIATED WITH INDOOR AIR POLLUTANT EXPOSURE

Respiratory illness, cancer, tuberculosis, perinatal outcomes including low birth weight, and eye diseases are the morbidities associated with indoor air pollution.

Respiratory Illness: The effect of air pollutants in general would depend on the composition of the air that is inhaled which will depend on the type of fuel used and the conditions of combustion, ventilation and duration for which the inhalation occur. The most commonly reported and obvious health effect of indoor air pollutants is the increase in the incidence of respiratory morbidity. Studies by the NIOH on the prevalence of respiratory symptoms in women using traditional fuels (biomass) (n=175) and LPG (n=99), matched for economic status and age, indicated that the relative risk (with 95% C.I.) for cough, and shortness of breath (dyspnoea) was 3.2 (1.6-6.7), and 4.6 (1.2-18.2) respectively.

Childhood acute respiratory infections

Acute lower respiratory infections: Acute respiratory infections (ARIs) are the single most important cause of mortality in children aged less than 5 years, accounting for around 3-5 million deaths annually in this age group. Many studies in developing countries have reported on the association between exposure to indoor air pollution and acute lower respiratory infections. The studies on indoor air pollution from household biomass fuel are reasonably consistent and, as a group, show a significant increase in risk for exposed young children compared with those living in households using cleaner fuels or being otherwise less exposed. Some of the studies carried out in India have reported no association between use of biomass fuels and ARI in children. In a case-control study in children under five years of age in south Kerala, where children with severe pneumonia as ascertained by WHO criteria were compared with those having nonsevere ARI attending out patient department, the fuel used for cooking was not a significant risk factor for severe ARI. Non-severe ARI controls may represent the continuum (predecessor) of the cases themselves. In a cross-sectional study in 642 infants dwelling in urban slums of Delhi and using wood and kerosene respectively, did not find a significant difference in the prevalence of acute lower respiratory tract infections and the fuel type.

Upper respiratory tract infections and otitis media: Studies on the relationship between indoor air pollution and acute upper respiratory infections in children both from developed and developing nations have not been able to demonstrate the relationship between the two. However, there is strong evidence that exposure to environmental tobacco smoke causes middle ear disease. A recent meta-analysis reported an odds ratio of 1.48 (1.08-2.04) for recurrent otitis media if either parent smoked, and one of 1.38 (1.23-1.55) for middle ear effusion in the same circumstances. A clinic based case-control study of children in rural New York state reported an adjusted odds ratio for otitis media, involving two or more separate episodes, of 1.73 (1.03-2.89) for exposure to woodburning stoves.

Chronic pulmonary diseases

Chronic obstructive pulmonary disease and chronic corpulmonale: In developed countries, smoking is responsible for over 80% of cases of chronic bronchitis and for most cases of emphysema and chronic obstructive pulmonary disease. It was pointed out to the relationship between exposure to indoor air pollutants and chronic obstructive lung disease leading to chronic corpulmonale. These studies showed that in India, the incidence of chronic corpulmonale is similar in men and women despite the fact that 75% of the men and only 10% women are smokers. Further analysis of the cases of chronic corpulmonale in men and women showed that chronic corpulmonale was more common in younger women. Chronic corpulmonale seemed to occur 10-15 years earlier in women. The prevalence of chronic corpulmonale was lower in the southern states than the northern states of India. This is attributed to higher ambient temperatures during most part of the year allowing for greater ventilation in the houses during cooking. The authors attributed this higher prevalence of chronic corpulmonale in women to domestic air pollution as a result of the burning of solid biomass fuels leading to chronic bronchitis and emphysema which result in chronic corpulmonale. Subsequent studies in India confirmed these findings. Numerous studies from other countries, including ones with cross-sectional and case-control designs, have reported on the association between exposure to biomass smoke and chronic bronchitis or chronic obstructive pulmonary disease.

Pneumoconiosis

Pneumoconiosis is a disease of industrial workers occupationally exposed to fine mineral dust particles over a long time. The disease is most frequently seen in miners. Cases of respiratory morbidity who did not respond to routine treatment and whose radiological picture resembled pneumoconiosis have been reported in Ladakh. However, there are no industries or mines in any part of Ladakh and therefore exposure to dust from these sources was ruled out. Two factors considered responsible for the development of this respiratory morbidity were (i) Exposure to dust from dust storms. In the spring dust storms occur in many parts of Ladakh. During these storms the affected villages are covered by a thick blanket of fine dust, and the inhabitants are exposed to a considerable amount of dust for several days. The frequency, duration and severity of these dust storms vary considerably from village to village; (ii) Exposure to soot – due to the severe cold in Ladakh, ventilation in the houses is kept at a minimum. The fire place is used for both cooking and heating purposes. To conserve fuel during non-cooking periods, the wood is not allowed to burn quickly but is kept smouldering to prolong its slow heating effect. The inmates are thus exposed to high concentrations of soot.

The clinico-radiological investigations of 449 randomly selected villagers from three villages having mild, moderate and severe dust storms showed prevalence of pneumoconiosis of 2.0, 20.1 and 45.3% respectively. The chest radiographs of the villagers showed radiological characteristics which were indistinguishable from those found in miners and industrial workers suffering from pneumoconiosis. The dust concentrations in the kitchens without chimneys varied from 3.22 to 11.30 mg/m^3 with a mean of 7.50 mg/m^3. The free silica content of these dust samples was below 1%. Dust samples sufficient to allow measurement of the dust concentrations could not be collected during the periods of dust storms. A preliminary analysis of the settled dust samples collected immediately after the storms indicated that about 80% of the dust was respirable and the free silica content ranged between 60 and 70%. Detailed statistical analysis of the data showed that the frequency of dust storms, use of chimney in the houses and age were the most important factors related to the development of pneumoconiosis.

Thus, the results of medical and radiological investigations positively established the occurrence of pneumoconiosis in epidemic proportion. Exposure to free silica from dust storms and soot from domestic fuel were suggested as the causes of pneumoconiosis. Low oxygen levels or some other factor associated with high altitude may be an important contributory factor in causation of pneumoconiosis because it has been reported that the miners working at high altitude are more prone to develop pneumoconiosis than their counterparts exposed to the same levels of dust and working in the mines at normal altitude.

Lung Cancer

The link between lung cancer in Chinese women and cooking on an open coal stove has been well established. Smoking is a major risk factor for lung cancer, however, about two-thirds of the lung cancers were reported in non-smoking women in China, India and Mexico. The presence of previous lung disease, for example tuberculosis which is common in Indian women, is a risk factor for development of lung cancer in non-smokers65. The smoke from biomass fuels contain a large number of compounds such as poly aromatic hydrocarbons, formaldehyde, etc. known for their mutagenic and carcinogenic activities, but there is a general lack of epidemiological evidence connecting lung cancer with biomass fuel exposure. The factors associated with rural environment may have a modulating effect on the occurrence of lung cancer and therefore the low incidence of lung cancer in Indian women should not lead to a final conclusion of no link between biomass exposure and lung cancer. It may be concluded that at present there is limited evidence of indoor exposure from coal fires leading to lung cancer and there is no evidence for the biomass fuels. Further investigations are needed to reach definite conclusions.

Pulmonary Tuberculosis

It was recently reported the association between use of biomass fuels and pulmonary tuberculosis on the basis of analysis of data collected on 260,000 Indian adults interviewed during the 1992-93 National Family Health Survey. Persons living in households burning biomass fuels were reported to have odd ratio of 2.58 (1.98-3.37) compared to the persons using cleaner fuel, with an adjustment for confounding factors such as separate kitchen, indoor overcrowding, age, gender, urban or rural residence and caste. The analysis further indicated that, among persons aged 20 years and above, 51% of the prevalence of active tuberculosis was attributed to smoke from cooking fuel. However, this study has inherent weakness that the cases of tuberculosis were self reported. There is strong possibility of false reporting as no investigation was done to confirm the reliability of the reporting. Similar findings were reported from northern India. This study did not control for the confounding factors except for age. There is experimental evidence to show that the exposure to wood smoke may increases susceptibility of the lungs to infections. Exposure to smoke interferes with the mucociliary defences of the lungs and decreases several antibacterial properties of lung macrophages, such as adherence to glass, phagocytic rate and the number of bacteria phagocytosed. Chronic exposure to tobacco smoke also decreases cellular immunity, antibody production and local bronchial immunity, and there is increased susceptibility to infection and cancer. Indeed, tobacco smoke has been associated with tuberculosis. Although the evidence in favour of tuberculosis associated with biomass fuel exposure is extremely weak, there is a theoretical possibility of such an association and considering the public health importance of the problem further experimental and epidemiological studies are necessary.

Cataract

During cooking particularly with biomass fuels, air has to be blown into the fire from time to time especially when the fuel is moist and the fire is smouldering. This causes considerable exposure of the eyes to the emanating smoke. In a hospital-based case-control study in Delhi the use of liquefied petroleum gas was associated with an adjusted odds ratio of 0.62 (0.4-0.98) for cortical, nuclear and mixed, but not posterior sub capsular cataracts in comparison with the use of cow dung and wood. An analysis of over 170,000 people in India75 yielded an adjusted odds ratio for reported partial or complete blindness of 1.32 (1.16-1.50) in respect of persons mainly using biomass fuel compared with other fuels after adjusting for socio-economic, housing and geographical variables; there was a lack of information on smoking, nutritional state, and other factors that might have influenced the prevalence of cataract. It is believed that the toxins from biomass fuel smoke are absorbed systematically and accumulate in the lens resulting in its opacity. The growing evidence that environmental tobacco smoke causes cataracts is supportive.

Adverse Pregnancy Outcome

Low birth weight (LBW) is an important public health problem in developing nations attributed mainly to undernutrition in pregnant women. Low birth weight has serious consequences including increased possibility of death during infancy. Exposure to carbon monoxide from tobacco smoke during pregnancy has been associated with LBW. Levels of carbon monoxide in the houses using biomass fuels are high enough to result in carboxyhaemoglobin levels comparable to those in smokers. In rural Guatemala, babies born to women using wood fuel were 63 g lighter than those born to women using gas and electricity, after adjustment for socio-economic and maternal factors. A study carried out in Ahmedabad reported an excess risk of 50% of stillbirth among women using biomass fuels during pregnancy. An association between exposure to ambient air pollution and adverse pregnancy outcome has been widely reported. Considering the association of LBW with a number of disease conditions later in life, there is a need for further studies.

INTERVENTION

Adequate evidence exists to indicate that indoor air pollution in India is responsible for a high degree of morbidity and mortality warranting immediate steps for intervention. The intervention programme should include (i) Public awareness; (ii) Change in pattern of fuel use; (iii) Modification in stove design; (iv) Improvement in the ventilation; and (v) Multisectoral approach.

Public Awareness

The first and the most important step in the prevention of illnesses resulting from biomass fuels is to educate the public, administrators and politicians to ensure their commitment and promoting awareness of the long-term health effects on the part of users. This may lead to people finding ways of minimizing exposure through better kitchen management and infant protection.

Change in Pattern of Fuel Use

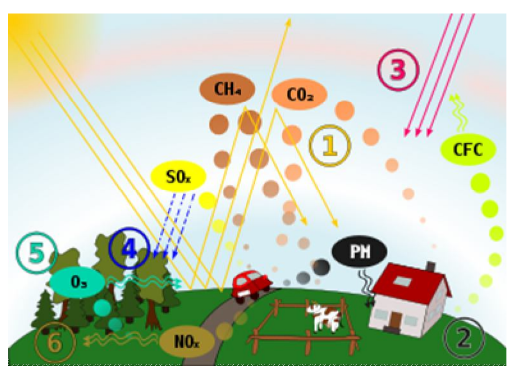
The choice of fuel is mainly a matter of availability, affordability and habit. The gobar gas plant which uses biomass mainly dung has been successfully demonstrated to produce economically viable quantities of cooking gas and manure. Recently, the Government of Andhra Pradesh has introduced a programme called the Deepam Scheme to subsidize the cylinder deposit fee for women from households with incomes below the poverty line to facilitate the switch from biomass to LPG. Such schemes will encourage the rural poor to use cleaner fuels. The use of solar energy for cooking is also recommended.

Modification in Stove Design

Use of cleaner fuels should be the long-term goal for the intervention. Till this goal is achieved, efforts should be made to modify the stoves to make them fuel efficient and provide them with a mechanism (e.g. chimney) to remove pollutants from the indoor environment. Several designs of such stoves have been produced. NIOH study showed significant decrease in levels of SPM, SO2, NOx and formaldehyde with specially designed smokeless stoves in comparison with traditional cooking stoves. However, they have not been accepted widely. Large scale acceptance of improved stoves would require determined efforts. The most important barriers to new stove introduction are not technical but social.

Improvement in Ventilation

In many parts of the country poor rural folk are provided with subsidized houses under various government/international agencies aided schemes. Ventilation in the kitchen should be given due priority in the design of the houses. In existing houses, measures such as putting a window above the cooking stove and providing cross ventilation through the door may help in diluting the pollution load.



Multisectoral Approach

Effective tackling of indoor air pollution requires collaboration and commitment between agencies responsible for health, energy, environment, housing and rural development.

Indoor air pollution and urban air quality are listed as two of the world's worst pollution problems in the 2008 Blacksmith Institute World's Worst Polluted Places report [1].

Before flue gas desulfurization was installed, the emissions from this power plant in New Mexico contained excessive amounts of sulfur dioxide.

Schematic drawing, causes and effects of air pollution: (1) greenhouse effect, (2) particulate contamination, (3) increased UV radiation, (4) acid rain, (5) increased ground level ozone concentration, (6) increased levels of nitrogen oxides.

An air pollutant is known as a substance in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made [2]. Pollutants can be classified as primary or secondary. Usually, primary pollutants are directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone — one of the many secondary pollutants that make up photochemical smog. Some pollutants may be both primary and secondary: that is, they are both emitted directly and formed from other primary pollutants.

About 4 percent of deaths in the United States can be attributed to air pollution, according to the Environmental Science Engineering Program at the Harvard School of Public Health.

Major primary pollutants produced by human activity include:

- Sulphur oxides (SO_x) - especially sulphur dioxide, a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Since coal and petroleum often contain sulphur compounds, their combustion generates sulfur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain [2]. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.
- Nitrogen oxides (NO_x) - especially nitrogen dioxide are emitted from high temperature combustion. Can be seen as the brown haze dome above or plume downwind of cities. Nitrogen dioxide is the chemical compound with the formula NO_2. It is one of the several nitrogen oxides. This reddish-brown toxic gas has a characteristic sharp, biting odor. NO_2 is one of the most prominent air pollutants.
- Carbon monoxide - is a colorless, odorless, non-irritating but very poisonous gas. It is a product by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.
- Carbon dioxide (CO_2) - a colorless, odorless, non-toxic greenhouse gas associated with ocean acidification, emitted from sources such as combustion, cement production, and respiration
- Volatile organic compounds - VOCs are an important outdoor air pollutant. In this field they are often divided into the separate categories of methane (CH_4) and non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming. Other hydrocarbon VOCs are also significant greenhouse gases via their role in creating ozone and in prolonging the life of methane in the atmosphere, although the effect varies depending on local air quality. Within the NMVOCs, the aromatic compounds benzene, toluene and xylene are suspected carcinogens and may lead to leukemia through prolonged exposure. 1,3-butadiene is another dangerous compound which is often associated with industrial uses.
- Particulate matter - Particulates, alternatively referred to as particulate matter (PM) or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to particles and the gas together. Sources of particulate matter can be manmade or natural. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols. Averaged over the globe, anthropogenic aerosols—those made by human activities—currently account for about 10 percent of the total amount of aerosols in our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease,[3] altered lung function and lung cancer.
- Persistent free radicals connected to airborne fine particles could cause cardiopulmonary disease [4, 5].
- Toxic metals, such as lead, cadmium and copper.

- Chlorofluorocarbons (CFCs) - harmful to the ozone layer emitted from products currently banned from use.
- Ammonia (NH_3) - emitted from agricultural processes. Ammonia is a compound with the formula NH_3. It is normally encountered as a gas with a characteristic pungent odor. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous.
- Odors — such as from garbage, sewage, and industrial processes
- Radioactive pollutants - produced by nuclear explosions, war explosives, and natural processes such as the radioactive decay of radon.

Secondary pollutants include

- Particulate matter formed from gaseous primary pollutants and compounds in photochemical smog. Smog is a kind of air pollution; the word "smog" is a portmanteau of smoke and fog. Classic smog results from large amounts of coal burning in an area caused by a mixture of smoke and sulfur dioxide. Modern smog does not usually come from coal but from vehicular and industrial emissions that are acted on in the atmosphere by ultraviolet light from the sun to form secondary pollutants that also combine with the primary emissions to form photochemical smog.
- Ground level ozone (O_3) formed from NO_x and VOCs. Ozone (O_3) is a key constituent of the troposphere. It is also an important constituent of certain regions of the stratosphere commonly known as the Ozone layer. Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night. At abnormally high concentrations brought about by human activities (largely the combustion of fossil fuel), it is a pollutant, and a constituent of smog.
- Peroxyacetyl nitrate (PAN) - similarly formed from NO_x and VOCs.

Minor air pollutants include:

- A large number of minor hazardous air pollutants. Some of these are regulated in USA under the Clean Air Act and in Europe under the Air Framework Directive.
- A variety of persistent organic pollutants, which can attach to particulate matter.

Persistent organic pollutants (POPs) are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. Because of this, they have been observed to persist in the environment, to be capable of long-range transport, bioaccumulate in human and animal tissue, biomagnify in food chains, and to have potential significant impacts on human health and the environment.

Compilation of Air Pollutant Emission Factors

Sources of air pollution refer to the various locations, activities or factors which are responsible for the releasing of pollutants in the atmosphere. These sources can be classified into two major categories which are:

Anthropogenic sources (human activity) mostly related to burning different kinds of fuel-

- "Stationary Sources" include smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices.
- "Mobile Sources" include motor vehicles, marine vessels, aircraft and the effect of sound etc.
- Chemicals, dust and controlled burn practices in agriculture and forestry management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.
- Fumes from paint, hair spray, varnish, aerosol sprays and other solvents
- Waste deposition in landfills, which generate methane. Methane is not toxic; however, it is highly flammable and may form explosive mixtures with air. Methane is also an asphyxiant and may displace oxygen in an enclosed space. Asphyxia or suffocation may result if the oxygen concentration is reduced to below 19.5% by displacement
- Military, such as nuclear weapons, toxic gases, germ warfare and rocketry

Natural sources

- Dust from natural sources, usually large areas of land with little or no vegetation
- Methane, emitted by the digestion of food by animals, for example cattle
- Radon gas from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking
- Smoke and carbon monoxide from wildfires
- Vegetation, in some regions, emits environmentally significant amounts of VOCs on warmer days. These VOCs react with primary anthropogenic pollutants—specifically, NO_x, SO_2, and anthropogenic organic carbon compounds—to produce a seasonal haze of secondary pollutants.[6]
- Volcanic activity, which produce sulfur, chlorine, and ash particulates

Emission factors

Compilation of Air Pollutant Emission Factors

Air pollutant emission factors are representative values that people attempt to relate the quantity of a pollutant released to the ambient air with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages.

The United States Environmental Protection Agency has published a compilation of air pollutant emission factors for a multitude of industrial sources.[7] The United Kingdom, Australia, Canada and many other countries have published similar compilations, as well as the European Environment Agency [8-12]. The large proportion of time that most people spend inside air-conditioned spaces increases the likelihood that poor indoor quality may cause adverse reactions such as allergies, eye irritation, headaches, feeling of confusion, and drowsiness as well as more serious long term effects. Carbon dioxide levels can be used as an indicator to evaluate whether adequate ventilation is taking place in the building. A high concentration of CO_2 may indicate that other contaminants in the building may be concentrating. Problems associated with high CO_2 are drowsiness, fatigue, and sick building syndrome. Environmental tobacco smoke (ETS) is the major sources of indoor air contamination. Inhalation of ETS is commonly termed as "second hand smoking" or "passive smoking". The ubiquitous nature of ETS in indoor environment indicates that some unintentional inhalation of ETS by non-smokers is inevitable. ETS is a dynamic and complex mixture of more than 4000 chemicals found in both vapour and particle phase. The USEPA has classified ETS as a known human carcinogen that it's responsible for ~ 3000 lung cancer deaths every year in US. Among other possible sources of contaminants are: gas ranges that mal function or are used as heat sources, improperly ventilated fireplaces, furnaces wood or coal stoves, gas water heaters and gas clothes dryers and improperly used kerosene or gas space heaters.

The gaseous pollutants from these combustion sources include some identified as prominent atmospheric pollutants such as CO, NO_2 and SO_2. Carbon monoxide causes asphyxiation. Accumulation of this odourless gas, colourless gas may result in varied symptoms deriving from the compounds or in combination with haemoglobin, forming carboxyhaemoglobin and disrupting oxygen transport. The elderly, the foetuses, and people with cardiovascular and pulmonary diseases are particularly sensitive to elevated CO levels. Methyl chloride found in some common household products like paint strippers, can be metabolized to form CO. Studies involving controlled exposure have shown CO exposure shortens time of onset of angina in individuals with chronic obstructive pulmonary disease (COPD). At room temperature VOCs are emitted as gases from certain solids or liquids. These include pesticides, solvents, and cleaning agents. Products used in home, office, school, and arts and hobby activities emit a wide array of VOCs. These products include scents, hair sprays, rugs, oven cleaners, dry-cleaning fluids, home furnishings, office materials like copiers, certain printers, correction fluids, graphics and craft material etc. Enamels emit toxic chemicals. In fact, lead dust or fumes from paints can cause mental retardation and learning disabilities in children, apart from rising blood pressure and damaging the brain, kidneys and nervous system. During summers, the blades of a fan collect dust particles, which are reservoirs of fungi and bacteria. The fashion of using aerosol perfumes, air fresheners and deodorizers is harmful and risky for health. Pleasant-looking cosmetics like nail polish contain dangerous chemicals like formaldehyde resin, acetone, xylene and phenol that cause headache, respiratory problems, lung irritation and cancer. It's essential to take an about-turn in terms of modern lifestyle with such an exposure to so many chemicals even at home.

Despite petrol's benzene (C_6H_6) content being lowered from 3 per cent to 1 per cent in 2000-2001, there has been no significant effect on the current ambient levels of this carcinogenic chemical. Benzene levels in air continue to be high according to two studies: Central Pollution Control Board's (CPCB's) Highlights2005 [indicates that the annual maximum concentration of benzene in ambient air in Delhi's Sirifort Area was as high as 17.9 $\mu g/m^3$; the annual mean concentration of benzene was observed at 9.1 $\mu g/m^3$.] and a Current Science paper (Vol.91, No.1o, 2006) by researchers of Nagpur-based National Environmental Engineering Research Institute (NEERI). In India there is no prescribed safety limits for benzene till now. In 2005, CPCB intended to set the limit at 10$\mu g/m^3$, which was progressively to be reduced to 5 $\mu g/m^3$ by 2010.The result of 10 years of air pollution interventions could be summarised as a mixed bag for Indian citizens. While the levels of noxious pollutants like sulphur dioxide and nitrogen oxide are down, lung-ailing pollutants like suspended particular matter (SPM) have maintained a constant level, thanks to the booming auto industry. This is what a comparative study of air pollution levels in 17 cities by the CPCB has found. Respirable suspended particulate matter (RSPM) and SPM levels in cities like Agra, Ahmadabad, Delhi, Faridabad, Jharia, Jodhpur, Kolkata, Lucknow and Mumbai are still above national standards. In all these cities, the vehicle population has increased by about 40 per cent since 2000. A new study carried out by Junfeng Liu of Princeton University and a team of researchers, has determined that unseen and odourless, microscopic particles of air pollutants wafting overseas and across continents kill some 380,000 people each year. Exhaust from diesel engines, sulphur from coal fired power plants, and desert dust swirl into an insidious cocktail of tiny particles that can spend weeks airborne. The most harmful are the smallest, less than 2.5 μ in diameter. When inhaled, they can irritate the lungs or pass directly into the bloodstream and damage arteries, according to Discovery News.

Following a recent study on environmental of industrial clusters across the country, the Union Ministry of Environment and Forest (UMoEF) has decided to put a brake on all development projects that need a clearance from it. For Rajasthan, the four industrial clusters of Bhiwadi, Jodhpur, Pali and Jaipur were chosen. While the first three were found to be "critically polluted" with their Comprehensive Environmental Pollution Index (CEPI) being 82.91, 75.19 and 73.73 respectively, the CEPI for Jaipur stood at 66.82 with the study terming it as "severely polluted". It's after this study that the ministry issued the memorandum in an effort to restore environmental balance in these clusters. The study has termed all clusters with CEPI higher than 70s critically polluted while those between 60 and 70 has been termed as severely polluted. The study recommended surveillance and pollution control measures for the severely polluted areas while urging detailed investigations in terms of damage and formulation of appropriate policy for critically polluted clusters. The ministry's decision followed a study by CPCB in association with the IIT, New Delhi, on environmental assessment of industrial clusters across the country based on CEPI. The index is a measure of the air, water and land pollution of cluster.

Air pollution from growing vehicular traffic, cutting down of trees to build express highways and flyovers and the hazards from industrial effluents have sharply increased the incidence of a range of diseases , from asthma to cancer to mental retardation, caused by increasing levels of lead (Pb)in the blood stream. Air pollution has become a devastating child killer throughout Asia. Children living in cities are unintended victims of the rapid industrialization and urbanization of most of Asian countries, poisoned by breathing air polluted by motor vehicle exhausts and industrial smokestacks. But kids in rural areas don’t escape harm either. Children die every year from breathing smoke from fires that turn their own homes into death traps. Because diseases tied to environmental factors can have more than one cause, it’s impossible to state flatly how many children are victims of air pollution. But combined statistics from WHO, private health groups, medical journals and hospital officials point to an inescapable conclusion: From teeming cities to tiny rural villages, every year at least 1 million Asian children are dying or suffering life- shortening diseases, such as respiratory infections and pneumonia, that are brought on by toxic air. Throughout Asia the signs of a huge problem are inescapable. In New Delhi, a survey of 20 thousand school children found that one in every eight had asthma. For children in China's cities, just breathing is the equivalent of smoking two packs of cigarettes a day. Respiratory disease isn't the only problem brought out by air pollution. In Bandung, Indonesia, examinations of 62 schoolchildren found that nearly half had dangerously high levels of lead in their blood from air polluted by motor vehicles. The threat begins even before birth. A Taiwanese study found a correlation between maternal exposure to sulphur dioxide (SO_2) during the first trimester of pregnancy and lowered birth weight. Newborns in the Philippines are showing high levels of Pb, mercury (Hg), cadmium (Cd) and copper (Cu) in their blood. And in Bangkok, physicians have found deadly particulates in the umbilical cords of newborn babies.

In a new report entitled "Smoke: the killer in the kitchen," the Intermediate Technology Development Group (ITDG), an international development charity based in the UK, estimates that more than half a million Asian children die annually from diseases brought on by indoor air pollution [Indoor pollution has long been regarded as the least important of all types of environmental pollution in our country. But the indoor environment provides on active field of action for a host of air borne pollutants ranging from chemical effluents to the more traditional by-products of smoking, cooking and heating. Various environment protection agencies have commissioned numerous studies to assess the impact of various consumer items we use on air pollution inside the four walls of a house. A report of the EPA revels that 'closed door pollution' is one of the top 18 environmental hazards that cause cancer in USA alone. The pollution deaths are mainly due to indoor pollutants like tobacco, smoke, aldehydes and other cancerous substances. A recent survey by researchers at The Energy and Resources (TERI), which covered several buildings in Delhi, revealed that indoor air pollution could be as toxic and as much of a nuisance as outdoor air pollution. People exposed to indoor pollutants over a long period of time may become more vulnerable to outdoor air pollutants. Such groups include the young, the elderly and the chronically ill, especially radon, asbestos particles, formaldehyde and volatile organic compounds (VOCs). Given the thrust on energy-efficiency in air-conditioned buildings, the level of ventilation with the external environment is rather low. These pollutants are often re-circulated indefinitely in offices and homes and can achieve high concentration levels. Most affected are children in rural areas of China and India.

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A new study carried out by Junfeng Liu of PC: Princeton University and a team of researchers, Washington (DC), as reported by EPA: Environmental Protection Agency, exhaust from diesel engines, sulphur from coal-fired power plants, and desert dust swirl into an insidious cocktail of tiny particles that can spend weeks airborne. It has been determined that unseen and adorless, microscopic particulate emigrating from foreign lands wafting overseas and across continents kill some 380,000 people prematurely each year. When the most harmful particles of < 2.5μ in diameter can irritate the lungs or pass directly into the bloodstream and damage arteries when inhaled, stated Discovery News. This has become a major health problem, especially in developing countries. But less clear is the effect that air pollution generated in regions like China and Southeast Asia has on far-off lands, like North America. Particulate pollution borne overseas that floats into Canada, Mexico and the US accounts for 6,600 premature deaths each year.

DON'T BREATHE YET

Exposure to diesel exhaust for a couple of hours a day is enough to give birth to blood vessels that feed tumours. Experiments on mice showed that exposure to diesel exhaust caused a six-fold increase in blood vessel formation in diseased mice and a four-fold increase in healthy mice breathing diesel fumes. There was no such increase in mice breathing filtered air. The exhaust activated a chemical signal and a protein associated with new blood vessel development. It lowered the activity of an enzyme that can suppress tumour growth (Toxicology Letters, online August 14, 2009).

THE DAWN OF POLLUTION

Health enthusiasts living near freeways should minimize their outdoor exercise timings during the early morning hours; they should also keep their windows closed through the night. It has been found that the level of air pollution to be really high during the pre-sunrise hours in the Interstate 10 freeway in Santa Monica, California. Researchers from the University of California (UC), Los Angeles and California Air Resources Board (CARB) equipped an electrical vehicle with no emissions of its own, with instruments to measure gaseous and particulate air pollutants, a global poisoning system, video monitor and instruments to measure temperature and winds. For pre-sunrise measurement, the vehicle was driven on a fixed route over two days in the summer and three days in the winter of 2008 between 4 and 7 am. Covering a distance of 3,600m this route passed through a dense residential neighborhood below the freeway. Covering a distance of 3,600m this route passed through a dense residential neighborhood below the freeway. Air pollutant concentrations were also measured on the freeway and streets transecting the route. During pre-sunrise hours, the traffic volume was to be 30 to 80 per cent lower compared to the morning or afternoon hours. However, the ultrafine particle concentrations were significantly high. This, the key researcher Shishan Hu explained, was due to unique metereological conditions existing in dawn. "Pre-sunrise, although traffic is relatively calm due to low wind speed and possible shallow temperature inversion, causing the pollutant to be trapped near the surface instead of being mixed and carried away. During the day traffic sources are more and strong mixing occurs" added Hu. During temperature inversion, temperature increases with height – a reversal of the normal pattern.

Due to specific wind direction, areas south of the freeway are down-wind/ hence the impact of the air pollutant was found to be down south (as far as 2,000m) during the pre-sunrise hours. Further north (upwind), it extended up to only 600m. Manju Mohan, professor at the Centre for Atmospheric Sciences (CASs), IIT, Delhi states, "These conditions can occur at sunrise causing a huge build up of pollutants at the ground level. But this situation mayn't last for long because the heat from the sun is strong enough to cause complete mixing of pollutants." Such wide pollutant-impact area downwind of a major roadways has much worse effects, Earlier researchers verified adverse conditions such as asthma and even morbidity associated with high pollutant concentrations in the vicinity of freeways the impact zone was identified to be 300m downwind side during daytime. Research pursued by Hu revealed much longer impact distance during pre-sunrise hours. This meant more people living in the vicinity of roadways have to be affected by freeways emissions.

RETINA VISUALS CAPTUR HEART

Digital photographs of the retina have revealed that healthy people exposed to high levels of air pollution have narrower retinal blood vessels. While past studies linked an increases in air pollution to a higher risk of death and hospitalization from heart disease, the study published in the November 2010 issue of PloS Medicine, is the first to establish that air pollution may adversely affect tiny blood vessels in the human body like those that supply blood to the heart and brain. A study in US cities led by researchers from University of Washington took retinal photographs of participant to measure retinal vessel diameters. They studied 4,607 people aged 45 to 84 years from the Multi-Ethnic Study of Atherosclerosis (MESA) to investigate the progression of subclinical and clinical cardiovascular disease. Nearly 30 per cent of the participants were living near a major roadway and none of them had a bad heart history. Fine particulate matter levels were measured at participants' homes over two years preceding the eye exam and on the eve of the eye exam. It was found that people exposed to fine particulate pollution and narrow retinal blood vessels. Longer the exposure, narrower the vessels. In people exposed to high air pollution for a shorter period, the vessels constricted as much happens with three years of ageing.

"As increase of three $\mu g/m^3$ in long-term fine particulate levels was linked to a one per cent decrease in arteriolar diameter. The difference in retinal blood vessel size of a person living in an area of high air pollution and of a person in an area of low air pollution would be the same as the difference between vessels of a person at 70 as compared to when they were 63," explained Sara D Adar, co-author of the study from the University of Michigan in USA. In case of short-term pollution, one can expect a 0.5 per cent decrease in thickness of the retinal arteriole, the same amount of change as for a difference of three years in age, was added. Narrowing of blood vessels in other organs can lead to a reduced blood flow to the heart and brain and be linked to angina, heart attacks and stroke, was cautioned.

TRAFFIC-DRIVEN DIABETES

Stress, frustration, rising blood pressure and breathing problems are common in motorists who spend hours in traffic jams. Now researchers have found another health consequence of traffic snarls – diabetes. Researchers from German Diabetes Centre and the Institute for Environment Medical Research at Heinrich Heine University, Germany, claim traffic-related air pollution could raise a woman's risk of developing type two diabetes. The study, led by Wolfgang Rathmann, started in 1985. It included 1,775 healthy women, all 55 years old. They were from the industrialized Rhur district of West Germany and nearby non-industrialized towns. It was examined that the participants again between 1990-2006 and found that 187 of them had developed diabetes. Data from environmental studies was collected to determine each woman's exposure to air pollution.

Living within 100 meters of busy roads more than doubled the risk of diabetes. Components of traffic pollution, particularly nitrogen dioxide and fine particulate matter, were significantly associated with a higher risk of the disease, was added. The more pollution a woman encountered, the greater was her chance of developing diabetes, the researchers concluded in the September, 2010 issue of Environmental Health Perspectives. Further it was called additional confirmatory research so that preventive measures could be taken. Rathmann commented,"The relevance of our study may be greater in some Asian countries, including India, because air pollution there is 10x higher than Germany." India is a capital to 50 million diabetics. The study is interesting and preliminary in Indian context.

POLLUTION AFFECTS FLOWER SCENT

The attractiveness of a flower diminishes when it does not emit fragrance. And not just we human beings, insects also stop taking interest in such a flower. Researchers from University of Virginia, USA, have sounded out a warning that fragrance in flowers may be short-lived. The cause is air pollution. This is crucial because both colour and fragrance attract insects towards flowers, thus helping pollination. The study shows that increasing levels of nitrogen oxides in the air react with and degrade hydrocarbons responsible for fragrance in flowers. Hydrocarbon reacts easily with nitrogen oxides (NO & NO_2) in the air to form ozone. This restricts the fragrance from travelling long distances – about 200 metres – thus making it difficult for insects to find flowers. Simulation studies showed that pre0industrial levels of air pollution, the fragrance of a flower could travel several kilometres. The hydrocarbon break down even they can be carried away by the wind, the findings were published in the March 2008 issue of the atmospheric Environment. The researchers used mathematical models to understand how common fragrance hydrocarbon – linalool, myrcene and ocimene – disperse in air.

In the highly polluted conditions 74 per cent of the fragrance gets killed within 200-300 metres of the source plant. This could mean that insects will take longer to find isolated flower patches and so their efficiency as pollinator could reduce. Besides, the ability of insects to differentiate between scents could also be affected since flower scents are a combination of various hydrocarbons, the researcher stated in the paper. “Pollution affects all aspects of plant biology, so it is not surprising that a flower’s fragrance is also altered. This could affect reproductive success in small populations. It could also lead to an increase in loss o genetic variation due to breeding, states A K Bhatanagar, head, Department of Botany, Delhi University.”

ACCELERATION IN VEHICLES INCREASES ULTRAFINE PARTICLES

When vehicle accelerate after stopping at a traffic light or a bus stop, the concentration of ultrafine particles increases, states a Hon Kong-based study. Ultrafine particles less than 0.1µ in diameter, are a fraction of particulate matter. It is considered as a significant human health concern because of its small size, large numbers and their ability to enter the respiratory tract and the circulatory system. The study aimed to evaluate the exposure of pedestrians to vehicular emission of ultrafine particles while walking near several high volume pedestrian walkways. Te findings were published in Aerosol and Air Quality Research (Vol. 8, No 1, 2008). Researchers chose three locations around a busy intersection in the city. It was found that the highest particle count in one of the locations and superimposed traffic patterns on the particle count versus time data for that location. Explains Hamilton Ysung, one of the lead researchers, “The effect of superimposing particle counts with traffic patterns supports correlation of traffic with heightened particle count.” For light-duty vehicles acceleration, many of the observed spikes of particle counts were small and lasted for around 10 to 45 seconds. It reached a maximum of $1.6x10^5$ particles per cubic centimetre before descending rapidly. In case of heavy-duty vehicles, large peaks with high and prolonged particle counts were observed some 20 minutes later. When the traffic light turned green, there was a sharp rise in particle counts within three seconds due to vehicle acceleration. Six seconds later, the particle counts rose to $5.4x\ 10^5$ particles per cubic centimetre after which it slowly descended over the next 35 seconds till the next red light.

“Sudden acceleration quickly emits a large number of particles. Heavy- duty vehicles such as trucks and buses are more likely to be using diesel and have higher levels of incomplete fuel combustion,” states Tsang. A study conducted on the Los Angeles freeway, which has the highest percentage of diesel vehicles (25 %) has also reported such peaks. “Vehicle acceleration causes much higher particle emission than idling vehicles because acceleration is when vehicles burn fuel in order to move,” Tsung adds. While these results are preliminary, they clearly suggest that reducing congestion would contribute greatly to improved air quality in the area thee by diminishing pedestrian exposure to toxic ultrafine particles.

SMOKING TREES LEADING POLLUTION

While we are yet to ascertain whether aerosols are warming or cooling our planet, a scientific team has traced a new source: deciduous trees. These are plants that shed their leaves seasonally. So for aerosols were described as particles of pollutants like sulphur dioxide (SO_2) black carbon (soot) and sea salt that remain suspended in air. Deciduous plants around 500 teragrammes (1 teragramme equals 10^{12} grammes) of carbon each year in the form of an organic compound called isoprene. The chemistry of what happens to the compound as it forms aerosols particles has, so far, been unclear. The team from CalTech in the US, University of Otago in the New Zealand and University of Copenhagen in Denmark, found isoprene is repeatedly oxidized in the atmosphere to form an epoxide, hitherto unknown, called dihydroxyepoxide. Epoxides are generally synthesized in the chemicals industry. It is rare to find such huge quantities of an epoxide, produced normally by plants. “Nothing is known by its fate in the atmosphere. Given the tendency of this epoxide to stick to acidic particles, it is likely to form aerosols under pristine conditions,” stated Fabien Paulot of CalTech.

Paul Weinberg, atmospheric science professor from the same institute, stated: “If you mix emissions from the city with the emissions from plants, they interact to alter the chemistry of the atmosphere.” Higher the concentration of aerosols, human induced or otherwise, foggier is the visibility in that area. Tadeusz Kleindienst, researcher at the US Environmental Protection Agency (EPA), stated that air quality regulatory agencies mainly pay attention to the effect of emissions from cars and industries; less is known about biogenic emissions. Hence their visibility predictions as well as other climatic predictions are not accurate. This study published in the August 8, 2009, issue of Science explains from where the Great Smoky Mountains are cover d by one of the largest patches of deciduous forests in North America.

A lack of ventilation indoors concentrates air pollution where people often spend the majority of their time. Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses. Building materials including carpeting and plywood emit formaldehyde (H_2CO) gas. Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled. Intentional air pollution is introduced with the use of air fresheners, incense, and other scented items. Controlled wood fires in stoves and fireplaces can add significant amounts of smoke particulates into the air, inside and out [13]. Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation. Carbon monoxide (CO) poisoning and fatalities are often caused by faulty vents and chimneys, or by the burning of charcoal indoors. Chronic carbon monoxide poisoning can result even from poorly adjusted pilot lights. Traps are built into all domestic plumbing to keep sewer gas, hydrogen sulfide, out of interiors. Clothing emits tetrachloroethylene, or other dry cleaning fluids, for days after dry cleaning.

Though its use has now been banned in many countries, the extensive use of asbestos in industrial and domestic environments in the past has left a potentially very dangerous material in many localities. Asbestosis is a chronic inflammatory medical condition affecting the tissue of the lungs. It occurs after long-term, heavy exposure to asbestos from asbestos-containing materials in structures. Sufferers have severe dyspnea (shortness of breath) and are at an increased risk regarding several different types of lung cancer. As clear explanations are not always stressed in non-technical literature, care should be taken to distinguish between several forms of relevant diseases. According to the World Health Organisation (WHO), these may defined as; asbestosis, lung cancer, and mesothelioma (generally a very rare form of cancer, when more widespread it is almost always associated with prolonged exposure to asbestos). Biological sources of air pollution are also found indoors, as gases and airborne particulates. Pets produce dander, people produce dust from minute skin flakes and decomposed hair, dust mites in bedding, carpeting and furniture produce enzymes and micrometre-sized fecal droppings, inhabitants emit methane, mold forms in walls and generates mycotoxins and spores, air conditioning systems can incubate Legionnaires' disease and mold, and houseplants, soil and surrounding gardens can produce pollen, dust, and mold. Indoors, the lack of air circulation allows these airborne pollutants to accumulate more than they would otherwise occur in nature.

Health effects

The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution.[14] "Epidemiological studies suggest that more than 500,000 Americans die each year from cardiopulmonary disease linked to breathing fine particle air pollution [14, 15]. A study by the University of Birmingham has shown a strong correlation between pneumonia related deaths and air pollution from motor vehicles [16]. Worldwide more deaths per year are linked to air pollution than to automobile accidents. Published in 2005 suggests that 310,000 Europeans die from air pollution annually Causes of deaths include aggravated asthma, emphysema, lung and heart diseases, and respiratory allergies. The US EPA estimates that a proposed set of changes in diesel engine technology (Tier 2) could result in 12,000 fewer premature mortalities, 15,000 fewer heart attacks, 6,000 fewer emergency room visits by children with asthma, and 8,900 fewer respiratory-related hospital admissions each year in the United States.The worst short term civilian pollution crisis in India was the 1984 Bhopal Disaster [17]. Leaked industrial vapors from the Union Carbide factory, belonging to Union Carbide, Inc., U.S.A., killed more than 25,000 people outright and injured anywhere from 150,000 to 600,000. The United Kingdom suffered its worst air pollution event when the December 4 Great Smog of 1952 formed over London. In six days more than 4,000 died, and 8,000 more died within the following months. An accidental leak of anthrax spores from a biological warfare laboratory in the former USSR in 1979 near Sverdlovsk is believed to have been the cause of hundreds of civilian deaths. The worst single incident of air pollution to occur in the United States of America occurred in Donora, Pennsylvania in late October, 1948, when 20 people died and over 7,000 were injured [18].

The health effects caused by air pollution may include difficulty in breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency room visits, more hospital admissions and premature death. The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, the individual's health status and genetics. A new economic study of the health impacts and associated costs of air pollution in the Los Angeles Basin and San Joaquin Valley of Southern California shows that more than 3800 people die prematurely (approximately 14 years earlier than normal) each year because air pollution levels violate federal standards. The number of annual premature deaths is considerably higher than the fatalities related to auto collisions in the same area, which average fewer than 2,000 per year [19].

Diesel exhaust (DE) is a major contributor to combustion derived particulate matter air pollution. In several human experimental studies, using a well validated exposure chamber setup, DE has been linked to acute vascular dysfunction and increased thrombus formation [20,21]. This serves as a plausible mechanistic link between the previously described association between particulate matter air pollution and increased cardiovascular morbidity and mortality.

Effects on cystic fibrosis

A study from around the years of 1999 to 2000, by the University of Washington, showed that patients near and around particulate matter air pollution had an increased risk of pulmonary exacerbations and decrease in lung function [22]. Patients were examined before the study for amounts of specific pollutants like Pseudomonas aeruginosa or Burkholderia cenocepacia as well as their socioeconomic standing. Participants involved in the study were located in the United States in close proximity to an Environmental Protection Agency. During the time of the study 117 deaths were associated with air pollution. Many patients in the study lived in or near large metropolitan areas in order to be close to medical help. These same patients had higher level of pollutants found in their system because of more emissions in larger cities. As cystic fibrosis patients already suffer from decreased lung function, everyday pollutants such as smoke, emissions from automobiles, tobacco smoke and improper use of indoor heating devices could further compromise lung function [23].

Chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease (COPD) includes diseases such as chronic bronchitis, emphysema, and some forms of asthma [24].

A study conducted in 1960-1961 in the wake of the Great Smog of 1952 compared 293 London residents with 477 residents of Gloucester, Peterborough, and Norwich, three towns with low reported death rates from chronic bronchitis. All subjects were male postal truck drivers aged 40 to 59. Compared to the subjects from the outlying towns, the London subjects exhibited more severe respiratory symptoms (including cough, phlegm, and dyspnea), reduced lung function (FEV_1 and peak flow rate), and increased sputum production and purulence. The differences were more pronounced for subjects aged 50 to 59. The study controlled for age and smoking habits, so concluded that air pollution was the most likely cause of the observed differences [25]. It is believed that much like cystic fibrosis, by living in a more urban environment serious health hazards become more apparent. Studies have shown that in urban areas patients suffer mucus hypersecretion, lower levels of lung function, and more self diagnosis of chronic bronchitis and emphysema [26].

Effects on children

Cities around the world with high exposure to air pollutants have the possibility of children living within them to develop asthma, pneumonia and other lower respiratory infections as well as a low initial birth rate. Protective measures to ensure the youths' health are being taken in cities such as New Delhi, India where buses now use compressed natural gas to help eliminate the “pea-soup” smog [27]. Research by the World Health Organization shows there is the greatest concentration of particulate matter particles in countries with low economic world power and high poverty and population rates. Examples of these countries include Egypt, Sudan, Mongolia, and Indonesia. In the United States, the Clean Air Act was passed in 1970, however in 2002 at least 146 million Americans were living in non-attainment areas—regions in which the concentration of certain air pollutants exceeded federal standards [28]. Those pollutants are known as the criteria pollutants, and include ozone, particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. Because children are outdoors more and have higher minute ventilation they are more susceptible to the dangers of air pollution.

Health effects in relatively "clean" areas

Even in areas with relatively low levels of air pollution, public health effects can be significant and costly. This is because effects can occur at very low levels and a large number of people breathe in such pollutants. A 2005 scientific study for the British Columbia Lung Association showed that a small improvement in air quality (1% reduction of ambient PM2.5 and ozone concentrations) would produce a $29 million in annual savings in the Metro Vancouver region in 2010 [29]. This finding is based on health valuation of lethal (death) and sub-lethal (illness) effects.

Reduction efforts

There are various air pollution control technologies and land use planning strategies available to reduce air pollution. At its most basic level land use planning is likely to involve zoning and transport infrastructure planning. In most developed countries, land use planning is an important part of social policy, ensuring that land is used efficiently for the benefit of the wider economy and population as well as to protect the environment. Efforts to reduce pollution from mobile sources includes primary regulation (many developing countries have permissive regulations), expanding regulation to new sources (such as cruise and transport ships, farm equipment, and small gas-powered equipment such as lawn trimmers, chainsaws, and snowmobiles), increased fuel efficiency (such as through the use of hybrid vehicles), conversion to cleaner fuels (such as bioethanol, biodiesel, or conversion to electric vehicles).

Control devices

The following items are commonly used as pollution control devices by industry or transportation devices. They can either destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere.

Particulate control

- Mechanical collectors (dust cyclones, multicyclones)
- Electrostatic precipitators: An electrostatic precipitator (ESP), or electrostatic air cleaner is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge. Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulate matter such as dust and smoke from the air stream.
- Baghouses: Designed to handle heavy dust loads, a dust collector consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system (distinguished from air cleaners which utilize disposable filters to remove the dust).
- Particulate scrubbers: Wet scrubber is a form of pollution control technology. The term describes a variety of devices that use pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.

Scrubbers

- Baffle spray scrubber
- Cyclonic spray scrubber
- Ejector venturi scrubber
- Mechanically aided scrubber
- Spray tower
- Wet scrubber

NOx control

- Low NOx burners
- Selective catalytic reduction (SCR)
- Selective non-catalytic reduction (SNCR)
- NOx scrubbers
- Exhaust gas recirculation
- Catalytic converter (also for VOC control)

VOC abatement

- Adsorption systems, such as activated carbon
- Flares
- Thermal oxidizers
- Catalytic converters
- Biofilters
- Absorption (scrubbing)
- Cryogenic condensers
- Vapor recovery systems

Acid Gas/SO_2 control
- ❖ Wet scrubbers
- ❖ Dry scrubbers
- ❖ Flue gas desulfurization

Mercury control
- ❖ Sorbent Injection Technology
- ❖ Electro-Catalytic Oxidation (ECO)
- ❖ K-Fuel

Dioxin and furan control

Miscellaneous associated equipment

Most Polluted World Cities by PM[30]	
Particulate matter, µg/m³ (2004)	**City**
169	Cairo, Egypt
150	Delhi, India
128	Kolkata, India (Calcutta)
125	Tianjin, China
123	Chongqing, China
109	Kanpur, India
109	Lucknow, India
104	Jakarta, Indonesia
101	Shenyang, China

List of countries by carbon dioxide emissions

Countries with the highest CO_2 emissions		
Country	**Carbon dioxide emissions per year (10^6 Tons) (2006)**	Percentage of global total Per capita CO_2 emissions[31]
China	6,103	21.5%
United States	5,752	20.2%
Russia	1,564	5.5%
India	1,510	5.3%
Japan	1293	4.6%
Germany	805	2.8%
United Kingdom	568	2.0%
Canada	544	1.9%
South Korea	475	1.7%
Italy	474	1.7%

List of countries by carbon dioxide emissions per capita

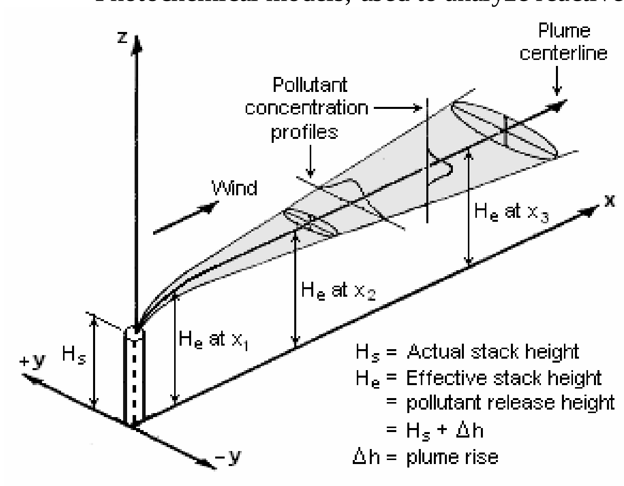
Countries with the highest per capita CO_2 emissions		
Country	**Carbon dioxide emissions per year (Tons per person) (2006)**	
Qatar	56.2	
United Arab Emirates	32.8	
Kuwait	31.2	
Bahrain	28.8	
Trinidad and Tobago	25.3	
Luxembourg	24.5	
Netherlands Antilles	22.8	
Aruba	22.3	
United States	19	
Australia	18.1	

Atmospheric dispersion

Atmospheric dispersion modeling

The basic technology for analyzing air pollution is through the use of a variety of mathematical models for predicting the transport of air pollutants in the lower atmosphere. The principal methodologies are:

- Point source dispersion, used for industrial sources.
- Line source dispersion, used for airport and roadway air dispersion modeling
- Area source dispersion, used for forest fires or duststorms
- Photochemical models, used to analyze reactive pollutants that form smog



Visualization of a buoyant Gaussian air pollution dispersion plume as used in many atmospheric dispersion models

The point source problem is the best understood, since it involves simpler mathematics and has been studied for a long period of time, dating back to about the year 1900. It uses a Gaussian dispersion model for buoyant pollution plumes to forecast the air pollution isopleths, with consideration given to wind velocity, stack height, emission rate and stability class (a measure of atmospheric turbulence).[32][33] This model has been extensively validated and calibrated with experimental data for all sorts of atmospheric conditions. The roadway air dispersion model was developed starting in the late 1950s and early 1960s in response to requirements of the National Environmental Policy Act and the U.S. Department of Transportation (then known as the Federal Highway Administration) to understand impacts of proposed new highways upon air quality, especially in urban areas. Several research groups were active in this model development, among which were: the Environmental Research and Technology (ERT) group in Lexington, Massachusetts, the ESL Inc. group in Sunnyvale, California and the California Air Resources Board group in Sacramento, California. The research of the ESL group received a boost with a contract award from the United States Environmental Protection Agency to validate a line source model using sulfur hexafluoride as a tracer gas. This program was successful in validating the line source model developed by ESL inc. Some of the earliest uses of the model were in court cases involving highway air pollution, the Arlington, Virginia portion of Interstate 66 and the New Jersey Turnpike widening project through East Brunswick, New Jersey.

Area source models were developed in 1971 through 1974 by the ERT and ESL groups, but addressed a smaller fraction of total air pollution emissions, so that their use and need was not as widespread as the line source model, which enjoyed hundreds of different applications as early as the 1970s. Similarly photochemical models were developed primarily in the 1960s and 1970s, but their use was more specialized and for regional needs, such as understanding

Ocean acidification and Greenhouse effect

The greenhouse effect is a phenomenon whereby greenhouse gases create a condition in the upper atmosphere causing a trapping of heat and leading to increased surface and lower tropospheric temperatures. Carbon dioxide emissions from combustion of fossil fuels are a source of greenhouse gas emissions. Other greenhouse gases include methane, hydrofluorocarbons, perfluorocarbons, chlorofluorocarbons, nitrogen oxides, and ozone.This effect has been understood by scientists for about a century, and technological advancements during this period have helped increase the breadth and depth of data relating to the phenomenon. Currently, scientists are studying the role of changes in composition of greenhouse gases from natural and anthropogenic sources for the effect on climate change. A number of studies have also investigated the potential for long-term rising levels of atmospheric carbon dioxide to cause increases in the acidity of ocean waters and the possible effects of this on marine ecosystems.

CONCLUSIONS

Indoor air pollution caused by burning traditional fuels such as dung, wood and crop residues causes considerable damage to the health of particularly women and children. There is evidence associating the use of biomass fuel with acute respiratory tract infections in children, chronic obstructive lung diseases, and pneumoconiosis in the residents of Ladakh villages. Lung cancer has been found to be associated with the use of coal in China, however, there is no evidence associating it with the use of biomass fuels. Cataract and adverse pregnancy outcome are the other conditions shown to be associated with the use of biomass fuels. The association of tuberculosis and chronic lung infections with the use of biomass fuels has not been proved. Finally, there is enough evidence to accept that indoor air pollution in India is responsible for a high degree of morbidity and mortality warranting immediate steps for intervention. The first and the most important step in the prevention of illnesses resulting from the use of biomass fuels is to educate the public, administrators and politicians to ensure their commitment for the improvement of public health. There is utmost requirement to collect better and systematic information about actual exposure levels experienced by households in different districts and climatic zones and develop a model for predicting the exposure levels based on fuel use and other household data therein (exposure atlas) to protect the health of children, women and elderly persons.

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