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A Review of Health Effects Associated with Indoor Air Pollution in Women and Children

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Abstract: ***Indoor air pollution is a major concern because of limited space inside home results in trap of pollutants for longer duration. Numerous studies have shown bad indoor air related health issues. An attempt has been made to enlist all such researches, their place of occurrence, observations and respective control measures. Ambient air has been widely investigated and insufficient data regarding household air pollution is the main impetuous behind this article. A substantial, deep and critical further scientific research is required to come out with better indoor mitigation measures.***

Keywords: Indoor pollutants sources, household air pollution, indoor mitigation, indoor health hazards

1. Introduction

One of the basic human needs is air. Clean air is very important for healthy human survival; on an average each person requires 10m³ of air per day. So the quality of air should be good enough as breathing dirty air can affect the person exposed to it [1]. In both developed and developing countries, air pollution has been linked with many health problems [2] [3]. Although outdoor air pollution and associated impacts have remained dominant worldwide but in the past recent years indoor air pollution has also gained quite attention as human exposure is a direct function of the level of pollution where they spend most of their time [4] [5]. In 2010, the total number of deaths related to indoor pollution outnumbered the number of deaths due to outdoor pollution [6] as air present inside buildings frequently contains more concentration of pollutants than the outside air because of the lack of ventilation and presence of strong emission sources inside. Since most of the people spend 80-90% of their time inside homes, offices and transport vehicles [7] [8] and [9] so air present inside buildings have strong influence on the health and working efficiency of the people [10] [11] and [12].One of the major pollution to which people get exposed inside buildings is particulate pollution which in turn is influenced by the emission rates of particle generating sources. Outdoor particles can enter inside through building cracks, windows and can influence inside particulate concentration [13]. There are several other activities which can influence air inside buildings like cigarette smoking [14] [15], cleaning activity [16] [17], candles or incense burning [18] [19], fireplaces [20], use of sprays, printers [21] [22] and unvented gas appliances can lead to higher indoor NO_2 concentration [23] [24].

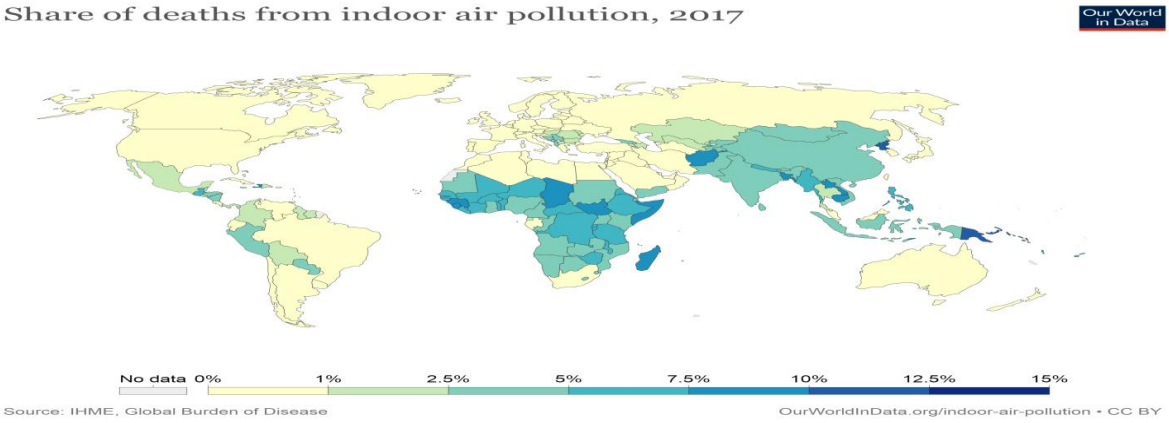
Cooking is one among major particulate emission practices contributing upto 20% of total indoor particulate matter [25] [26] [27] [28]. The concentration and type of particulates emitted depends upon the mode of cooking style [29]. Chemical characterization of the particulates originated indoor have shown various chemical species like F^-, Cl^-, PO_4^{3-}, NO_2^-, NO_3^-, SO_4^{2-}, Na^+ and various metals like Cd, Cr, Ni, Pb, Cu, Ti, Al, Zn, Fe, Ni and Zn [30]. These metals get released from metallic utensils cooking, crustal in origin, fossil fuel burning, and tobacco smoking inside, wood burning, or may have migrated from outdoor. Several other human activities like vacuuming, dust cleaning, showering etc may also lead to re-suspension of particles [31] [32]A major fraction of the world's population resides in rural areas and fulfills their energy demand from fuels like cow dung cakes, kerosene oil and wood [33]. In India, about 0.2 billion people are using fuel for cooking out of which; 49% use firewood; 8.9% cow dung cake; 1.5% coal, lignite, or charcoal; 2.9% kerosene; 28.6% liquefied petroleum gas (LPG); 0.1% electricity; 0.4% biogas; and 0.5% any other means [34].

The mortality rate linked with indoor smoke resulting from coal and biomass burning is 1.6 million annually and is considered as the eighth largest factor contributing to global burden diseases [35] [36]. Although many studies have taken place regarding outdoor air pollution and associated health impacts but a gap still exists in terms of knowledge and research interest regarding indoor air pollution in developing countries. So in this aspect, an effort has been made to fulfill this knowledge gap.

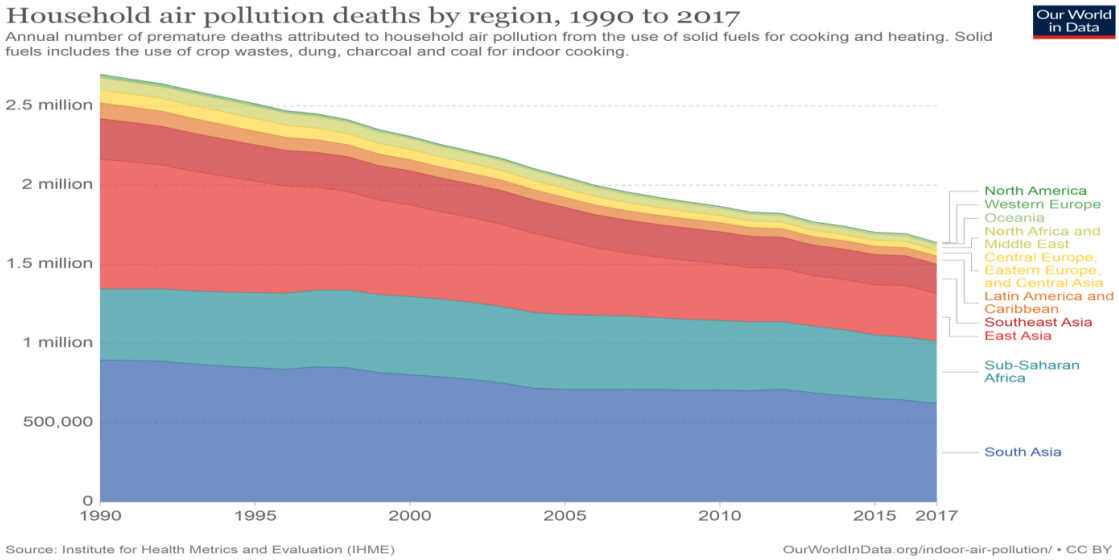
World's scenario in indoor pollution

Countries like Chad, South Sudan, Somalia, Afghanistan, Bangladesh and Papua New Guinea share highest number of deaths occurring due to indoor air pollution whereas India experiences nearly 5% of the same as shown in (Fig. 1). As depicted in (Fig. 2) the maximum number of deaths during the period of 1990-2017 has been observed in Asian countries followed by Africa, Europe and America. Institute for Health Metrics and Evaluation (IHME), has recognized Indoor air pollution as the fourth main leading reason of deaths in all age groups with high blood pressure, smoking and blood sugar as the first, second and third cause resulting in deaths (Fig. 3). On a global scale maximum initiatives

have been taken in developed nations in order to reduce household air pollution as shown in (Fig. 4) with India and many African countries still lacking behind in clean fuel adoption technology for cooking purpose.



Source [37]
Figure 1



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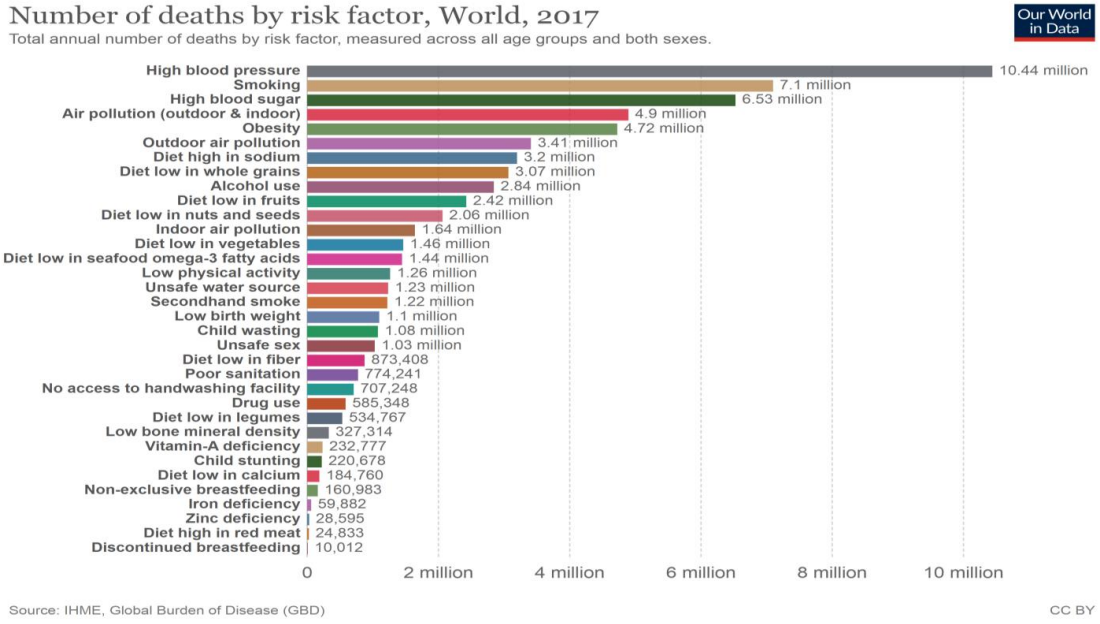

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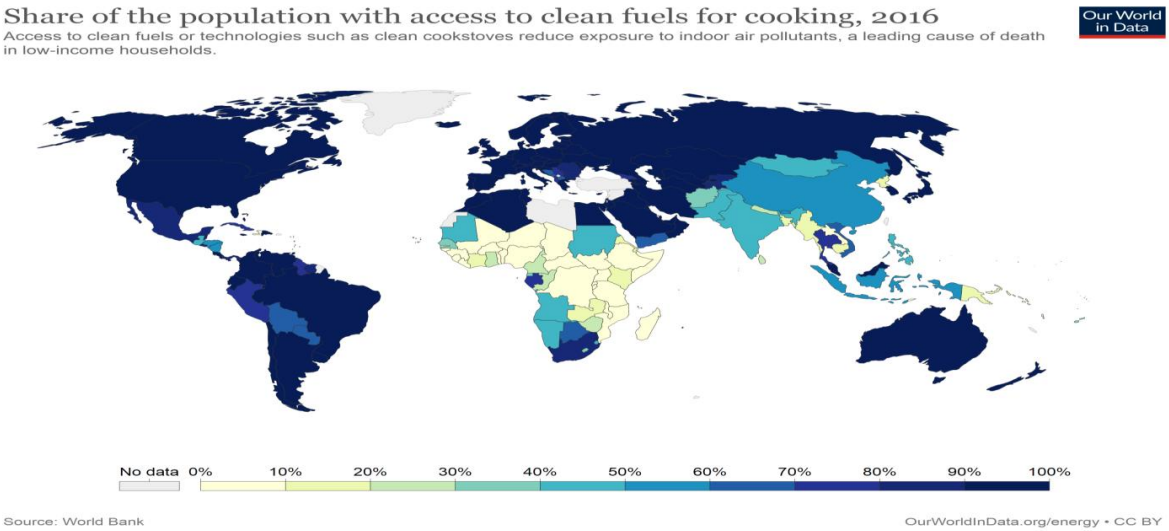

Source [38]
Figure 4

Indoor air pollutants

Indoor air pollutants can be outdoor or indoor in origin. A strong correlation has been noticed between respiratory diseases and air pollution [39] [40]. The effects caused via ingestion, dermal contact or by inhaling polluted air can be acute or chronic. Acute effects are those that occur for a short time period and disappear as soon as the exposure ends like headache, itching in eyes, running nose etc whereas chronic effects occur due to long term exposure to even low concentration of pollutants like chronic obstructive pulmonary disease, pulmonary tuberculosis etc. The various indoor air pollutants and associated health impacts are given in Table-I and particulates sources are given in table-II.

Table I: Indoor air pollutants, their sources and effects.

S. No.	Type of Pollutant	Sources	Effects
1.	Asbestos	Building material, (Roofing, Ceiling, Paper, floor tiles, cement products). Friction products (Automobile clutch, brake) Heat resistant fabrics (Gaskets Coatings).	Causes Mesothelioma i.e. cancer of lining of lungs.
2.	Carbon monoxide	Kerosene and gas space heaters, gas stoves, tobacco smoke etc.	Fatigue and chest pain at low concentration. brain function, impaired vision angina at moderate concentration. Headaches, dizziness, nausea, impaired vision etc at high concentration.
3.	Nitrogen dioxide	Combustion processes like gas stoves, tobacco smoke, kerosene heaters etc.	Causes irritation of eye, nose and throat, pulmonary edema, chronic bronchitis etc.
4.	Particulate matter	Cooking, Combustion activities like cigarette smoking, unvented space heaters, kerosene heaters, candle burning etc or may be of outdoor origin migrated inside.	Causes irritation of eye, nose and throat, various other respiratory problems.
5.	Lead	Lead paints when removed by scraping, sanding or open flame burning, lead dust from outdoor sources etc	abdominal pain, headaches, loss of appetite, fatigue, high blood pressure, numbness or tingling in the extremities, anemia and kidney failure.
6.	Formaldehyde	Wood products, building material and insulation, glues, paints and coatings, paper products etc.	Causes irritation of skin, eye, nose, and throat.
7.	Radon	Disintegration of U-238.	Cancer
8.	Tobacco smoke	Burning of tobacco products like cigarettes, cigars, pipes and smoke exhaled by smokers.	Causes cancer in lungs, heart disease and stroke.
9.	Volatile organic compounds	Paints, wood preservatives, dry cleaned clothes, cleansers and disinfectants, aerosol sparys building material and furnishings etc.	Irritation in nose, eye, throat and skin, nausea, fatigue, epitaxis, dizziness, dyspnea etc.
10.	Biological Pollutants	Pollens, bacteria, household pets, droppings of cockroaches, rodents and other pests.	Asthma, dizziness, watery eyes, coughing, lethargy, fever, allergic rhinitis and hypersensitivity pneumonitis.
11.	Ozone	Photocopying machines, Laser printers, air cleaners etc	Cough, throat irritation, shortness of breath, etc.

Source [41]

Table II: Indoor Particulates sources

S.NO	Ions/Metals	Sources	Literature confirming their origin
1.	NO_2^-, NO_3^-	Gas stoves	[42]
2.	Ti, Al, Fe	Crustal origin	[43]
3.	Cu, Zn	Fossil fuel combustion	[44]
4.	Mn, Ni	Automobile dust	[45]
5.	Cd, Cr, Ni Pb	Tobacco smoke	[46] [47]
6	Organic carbon	Cooking, Smoking	[48] [49]]
7	Elemental carbon	Vehicular emission	[50] [51]
8.	Acrolein, Hydrocarbon, nicotine, CO, NOx, Nitrosamines, Particulates	Tobacco smoke	[52]

2. Methodology

While compiling this review paper different sites were searched like PubMed, web of science, Google scholar and Wiley online library. Papers related to indoor air quality from all over the world were selected and tabulated from 1996 to 2019. Some of the content was directly investigated online using keywords like indoor aerosols, indoor air quality and health, indoor pollution, cooking fuel and associated health impacts, acute and chronic health impacts in women and children separately. The selection of the paper was made by looking at the title, abstract, if relevant only then, full paper was read and their findings were assembled in such a manner that a single glance of the tables can provide maximum information.

Health hazards to women

Cooking is one of the important daily tasks that almost every lady has to perform all over the world. On an average every lady spends six to seven hours per day in kitchen, hence are under more risk of experiencing respiratory health issues. Several studies have shown that extent of pollutant exposure is dependent on the type of fuel used for cooking like cooking in olive oil generates maximum particulates as compared with sunflower oil, method by which cooking is done and type of food being cooked, like cooking of fatty food is associated with high particulate emission rather than normal food [53]**.** A list of literature is given in table –III that conducted study on indoor air pollution and women health.

Table III: List of literature on indoor air pollution and women health

S. No	City	Sampling site	Study subject	Study results	References
1.	India	Residence	Biomass combustion v/s Asthma	Asthma cases higher in females using biomass as fuels than using cleaner fuels for cooking.	[54]
2.	China	Residence	Lung cancer among non-smokers females.	High lung cancer risk in females exposed to tobacco smoke, high frequency of cooking and solid fuels	[55]
3.	China	Residence	Lung cancer among non-smokers females.	High cancer risk in females who used to wait until fumes emit from cooking oil before cooking.	[56]
4.	India	Residence	Indoor air pollution as a risk factor for lung cancer.	Biomass fuel exposure had a significant risk in lung cancer development in passive as well as active smokers.	[57]
5.	Mozambique	Residence	Cooking fuel and respiratory symptoms among women.	Respiratory symptoms were observed more in women using wood for cooking purpose followed by using charcoal and LPG.	[58]
6.	India	Residence	Lung cancer among women due to domestic cooking fuel used by them.	Biomass fuel exposure is an important risk factor for development of lung cancer in addition to tobacco smoke exposure.	[57]
7.	Guatemala	Residence	Association between open indoor burning and respiratory problems.	Women using improved stoves had less respiratory problems than those using open indoor fire burning without chimney.	[59]
8.	India	Residence	Association between biomass, solid burning and preeclampsia and eclampsia symptoms in women.	Women using solid fuel had greater risk of developing preeclampsia and eclampsia symptoms than those using cleaner fuels.	[60]
9.	Mexico	Residence	Health impact of improved biomass stove on respiratory system in women.	Women using open fire had more respiratory problems than using improved biomass stove	[61
10.	Burkina	Residence	Associated between cooking fuel choice and respiratory heath problems in women.	Biomass as well as charcoal exposure was associated with more respiratory problems than those using LPG.	[62]
11.	Ethiopia	Residence	Relation between lung functioning, respiratory health problems and household fuel usage.	Reduced lung functioning and more respiratory problems in rural women using solid fuels as the only energy source.	[63]
12.	India	Residence	Prevalence of COPD in biomass fuel using women.	COPD occurrence was more in women using biomass and it was observed two times higher in women spending more than 2 hours in kitchen for cooking purpose.	[64]
13	Bangladesh	Residence	Respiratory problems among women using traditional biomass fuel and gas fuel.	Respiratory problems were significantly higher in women using biomass fuel for cooking purpose than those using gas fuel.	[65]
14.	India	Residence	Association of CB and AFO with household cooking fuel	Prevalence of CB and AFO was observed associated with type of fuel usage and was observed more in solid biomass	[66]

			usage.	fuels using women.	
15.	Africa	Residence	Effect of cooking fuel smoke on respiratory symptoms and lung functioning in women.	More respiratory symptoms were observed in using wood as cooking fuel.	[67]

Health hazards to children

Children below 5yrs are the most exposed group to household air pollution resulting from unprocessed biomass fuel burning at home. Children are more vulnerable to get infected by inhaling more polluted air closer to the ground. Pneumonia resulting from air pollution has been observed to be the leading cause of mortality among children. [68]**.** Many studies have confirmed that indoor air pollution exposure resulting in respiratory illness and lung cancer in children [69][70][71]. A list of such studies conducted at various places throughout the world is given in Table-IV.

Table IV: List of literature on indoor air pollution and children health

S. No	City	Sampling site	Study subject	Study results	References
1.	Dominican Republic	Residence	Effect of charcoal smoke on acute upper and lower respiratory infections (AURI and ALRI)	High RPM in households using charcoal and exposure to charcoal smoke increased the risk of AURI and ALRI in children.	[72].
2.	India	Residence	Effect of cooking fuel on respiratory diseases in children.	Cow dung cakes as cooking fuel was more associated with respiratory diseases.	[73].
3.	Scotland and England	Residence	Association between cooking gas and respiratory diseases in children.	More respiratory problems in children from homes where gas was used for cooking purpose than where electricity was used.	[69]
4.	Australia	Residence	Respiratory symptoms in children exposed to indoor NO_2 and gas stove.	More respiratory symptoms in children exposed to gas stoves and it was observed as most significant risk for respiratory symptoms.	[74]
5.	Australia	School	Respiratory effects associated with indoor NO_2 exposure.	Increased NO_2 exposure was associated with significant increase in cold, cough and sore throat.	[75]
6.	America	Residence	Respiratory illness due to NO_2 exposure in infants.	Respiratory illness and symptoms were observed but the incidence rate and duration of illness was not associated with NO_2 exposure.	[76].
7.	Zimbabwe	Residence	Indoor wood smoke exposure and respiratory diseases in children.	Significant association between wood smoke exposure and occurrence of respiratory illness.	[77].
8.	India	Residence	Indoor air pollution correlation with respiratory diseases.	Children in households having more pollutants inside were observed with more respiratory diseases.	[78]
9.	Bangladesh	Residence	Association between low birth weight child and indoor air pollution	Women using coal and wood as cooking fuel had more chances of having low birth weight child than those using clean fuels.	[79]
10.	India	Residence	Effect of air pollution on respiratory problems among children	More respiratory problems in children residing in households having more air pollution.	[80].
11.	Canada	Residence	Hospitalization for respiratory problems due to pollution in children	Positive correlation was observed between hospitalization for respiratory problems and pollution exposure.	[81]
12.	Sri Lanka	Residence	Effect of household air pollution due to solid biomass combustion on respiratory diseases in children.	Higher respiratory problems were observed in children residing in households using solid biomass and kerosene as cooking fuel whereas less risk was observed in households using cleaner fuels like LPG and electricity for cooking.	[82].
13.	Indonesia	Residence	Effect of household air pollution from solid fuel use and environment tobacco smoke in children.	Children exposed to solid biomass fuel had increased risk of respiratory problems.	[83]
14.	Bangladesh	Residence	Association of biomass fuel with respiratory symptoms among children.	Risk of respiratory symptoms in children was observed high in biomass using households than non-biomass fuel users.	[84]
15.	Bangladesh	Residence	Indoor exposure to particulate matter and occurrence of ALRI	Each hour for increase in concentration above 100 was associated with 7% increase in occurrence of ALRI in children.	[85]

Association between indoor air pollutants and health

Numerous health issues can result from exposure to indoor air pollution.

Acute lower respiratory infections (ALRI). ALRI include pneumonia, bronchitis and bronchiolitis can also result from solid fuel use inside homes and is one of the leading causes of deaths all over the world. Several studies have been carried out regarding ALRI resulting from indoor air pollution [72][85][86].

Chronic obstructive pulmonary disease (COPD). COPD is a common lung disease that blocks the air flow and makes

it difficult to breathe. A researcher confirmed that COPD can also result from indoor air pollution exposure [64].

Low birth weight in children. There may be several factors responsible for lower birth weight in children but one such study proved that mother's exposure to air pollution can also affect child's weight at birth [79].

Lung Cancer: Biomass burning releases large number of toxic and small size particles that can penetrate deep into the lungs and can result in cancer. A number of studies carried out also support that biomass smoke exposure can result in lung cancer [55] [56] [57].

Asthma: Multiple factors can be responsible for a person to become asthmatic like several studies support the idea that exposure to tobacco smoke can be a risk factor for asthma occurrence [55] [56] whereas various other workers validate that exposure to biomass and solid fuel smoke can also result in asthma [54] [88].

3. Case Studies

In majority, people spend 70-80% of the time indoor where cooking is one of the important pollutants generating activity. A large number of studies carried out in various parts of the world have shown health problems associated with solid biomass fuel, wood, dung and crop residues burning inside homes [4] [60] [86] [89] [90][91][92][[93]. The concentration of particles emitted during cooking depend on the type of food being cooked like fatty food takes more oil as well as long time to cook, so causes more pollution. Electrical cooking generates less particles and nitrogen dioxide in comparison to cooking on gas [42]**.** Several workers have observed that improvement in cooking stoves can decrease the risk of health associated problems linked with open biomass fuel cooking [59] [60] [62] [94] [95] [96]. In addition to cooking there are several other activities like indoor tobacco smoking is known to cause numerous respiratory health issues. Scientists also investigated tobacco deleterious impacts on health [55] [56] [97]. Presence of Indoor gaseous pollutants like CO_2 can hamper a person's long duration working ability by releasing several stress hormones in the body [98]. A researcher also found that installation of air cleaners can reduce the exposure level of particulates [99].

4. Recommendations

Since a large fraction of the population dies every year because of indoor air pollution. So there is a need of more advanced research in the respective field so as to have a better calculation of the diseases associated with the indoor air pollution. Following below mentioned measures can help in mitigating the problem.

Awareness

Awareness is one of the best weapons that can be utilized against indoor air pollution. Every single citizen including politicians and administrators must be educated about the ill health impacts associated with household air pollution. Only through education and awareness people can come to know how to protect themselves and what alternatives should be taken in order to reduce the menace.

Change in fuel consumption

The type of fuel (coal, wood and cow dung cakes etc) used for indoor cooking plays an important role in surging the issue of indoor air pollution. Affordability and feasibility are the two deciding factors for a fuel to be solely dependent upon. So government and stakeholders of a country should work on moving up the energy ladder to cleaner fuels by providing clean fuels like LPG, especially to the economically weaker sections of the society.

Cross ventilation

Building design also carries principal role in air circulation. Houses without windows and exhausts acts as pollution traps, so they should be constructed keeping in view so that proper aeration can take place. Exhaust fans should be installed in kitchen. Improved gas stoves designs with proper exit, chimney and better combustion efficiency should be promoted.

Formulation and implication of indoor air standards

Every country must be having outdoor air standards and in every conference more emphasis is given on problems arising from air pollution outdoor in origin rather on indoor air pollution. If not properly dealt with, indoor polluted air can lead to even more serious health issues. So stress should be laid upon formulating and implication of indoor air standards with the same significance as that of outdoor air standards. There should be monthly analysis regarding following of indoor air standards and violation of the same should be properly charged.

Indoor plants

Numerous plants like philodendron, spider plant, dracaena etc are known to keep air fresh inside home.

Improvement in cooking stoves

Earlier ladies used to cook openly with poor quality fuels like biomass but improvement in cooking stoves with proper fuel source, burning and exhaust can reduce the exposure levels**.**

Indoor air Research promotion

Research in context of indoor air is still lacking behind in many countries so the government of every country should encourage research in this particular field so that maximum health risks can be known and looked upon.

5. Conclusion

Though indoor air pollution is a worldwide serious issue, but, focused future research and investigations along with improved cooking and fuel consumption patterns, ventilation and awareness can prove useful in reducing health risks associated with it.

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