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Effect of Indoor Air Pollution on Child Development: A Research Review

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ABSTRACT

The air quality of our indoor environments majorly affects our health. Children are the most exposed to indoor air pollutants as they spend most of their time at home and indoors, the quality of air becomes a major concern in their course of development. While in rural areas the major indoor pollutants are the emissions from combustion sources, in urban areas the particulates and polycyclic aromatic hydrocarbons (PAHs) have chronic and long-term effects. The aim of this study is to review the available literature dealing with various effects of child development. The study showed the relationship between prenatal exposure to airborne PAHs and Child IQ. Children were monitored from in utero to 5 years of age, with determination of prenatal PAH exposure through personal air monitoring for the mothers during pregnancy. It was found that high PAHs level were inversely associated with IQ. The other study comprehended lung development with exposure to nitrogen dioxide, acid aerosols, particulate matter and elemental carbon. Lung function tests were performed annually for 8 years among the children and a decrease in Forced Expiratory Volume (FEV) was observed. The results of the study indicated that current ambient levels of air pollution have chronic and adverse effects on lung development in children leading to significant deficits in FEV as these children reach adulthood. In rural India, the risks associated with indoor air pollution are found to be extremely high. The study revealed that most of the rural households were exposed to acute upper and lower infections, the reason being the use of traditional fuels and poorly ventilated cooking areas. The study focuses on creating awareness towards the adverse effects of indoor air pollution specifically on children health, with reference to the existing studies.

1) INTRODUCTION

The effects of air pollution on health have been reported in many research studies over the past 30 years. These effects majorly include mortality, respiratory and cardiovascular diseases and hospitalizations, changes in lung function and asthma attacks. Air quality has significant effect on children, however, previous environmental regulation has not focused on the effects caused by air pollution exclusively in children. And despite the extent of this mounting problem, the health impacts on children due to exposure to indoor air pollutants have yet to become a central focus of research especially in developing countries. According to studies, prenatal exposure to airborne polycyclic aromatic hydrocarbons (PAHs) is inversely related to a child's intelligence [1]. There have also been studies which link urban air pollution with asthma risk and behavioural problems in children. New findings also link exposures to chemicals found in homes with childhood respiratory problems.

1.1 Indoor Air Pollutants

In the developed countries where energy efficiency improvements sometime make houses relatively airtight and raising pollutant levels, indoor air pollution has been a serious concern. But now with the construction of more tightly sealed buildings, reduced ventilation, use of synthetic materials for building and furnishing the issue has been taken into account in the sub-continent as well. In India, the greatest threat from indoor pollution is to rural areas, where some 0.8 billion people continue to rely on traditional fuels such as firewood and charcoal for cooking and heating (WHO. 2013) [2]. Concentrations of indoor pollutants in households that burn traditional fuels are alarming. Burning such fuels produces large amount of smoke and other air pollutants in the confined space of the home, resulting in high exposure. In 1992, the World Bank designated indoor air pollution in the developing countries as one of the four most critical global environmental problems [3]. Daily averages of pollutant level emitted indoors often exceed current WHO guidelines and acceptable levels. Although many hundreds of separate chemical agents have

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been identified in the smoke from bio-fuels, the four most serious pollutants are particulates, carbon monoxide, polycyclic organic matter, and formaldehyde. In this study our focus remains on the exposure to piperonyl butoxide (PBO), polycyclic aromatic hydrocarbons (PAHs) and phthalates.

1.2 Sources and their exposure

Indoor air pollution can begin within the building or can be drawn in from outdoors. **Volatile organic compounds** mainly originate from solvents and chemicals. The main indoor sources are perfumes, hair sprays, furniture polish, glues, air fresheners, moth repellents, wood preservatives and many other products used in the house. **Tobacco smoke** generates a wide range of harmful chemicals and is known to cause cancer. It is very well known that passive smoking causes a wide range of problems to the passive smoker, the person who is in the same room with a smoker and is not himself/herself a smoker, ranging from burning eyes, nose and throat irritation to cancer, bronchitis, severe asthma and a decrease in lung function. In several research papers it is showed that maternal smoking may play a significant role in childhood obesity. Data from the US Collaborative Perinatal Project, a study of 35,000 children born between 1959 and 1964, show that children of smokers had an increased risk of becoming overweight before the age of 8 compared with the offspring of non-smokers [4]. The link between maternal smoking and obesity was stronger in girls than in boys. If **pesticides** are used carefully and the manufacturers, instructions followed carefully they do not cause too much harm to the indoor air. But piperonyl butoxide (PBO) which is used to bolster the effects of pyrethroid pesticides, the most common pesticides used for professional pest control has been found to increase the risk of non-infectious cough among children exposed to these chemicals in the womb [5]. **Biological pollutants** include pollen from plants, mite, hair from pets, fungi, parasites and some bacteria. Most of them are allergens and can cause asthma, hay fever, and other allergic diseases. **Formaldehyde** is a gas that comes mainly from carpets, particle boards, and insulation foam. It causes irritation to the eyes and nose and may even cause allergies in some people. **Asbestos** is a major concern because it is suspected to cause cancer. **Radon** is a gas which is emitted naturally by the soil. It is due to modern houses having poor ventilation that it is confined inside the house causing harm to the dwellers. In a study from CCCEH (*Columbia Center for Children's Environmental Health*), researchers reported that children exposed to diethyl phthalate (DEP) and butylbenzyl phthalate (BBzP) have a greater risk of asthma-related airway inflammation [6]. Phthalates are used widely in consumer products, including plastics, vinyl flooring, and personal care products. Phthalate exposure can occur through ingestion, inhalation, and absorption through the skin.

1.3 Effects of Indoor Air Pollutants on Children Health

Nearly 2 million people a year die prematurely from illness attributable to indoor air pollution due to solid fuel use. Among these deaths, 44% are due to pneumonia, 54% from chronic obstructive pulmonary disease (COPD), and 2% from lung cancer. Nearly half of deaths among children under five years old from acute lower respiratory infections (ALRI) are due to particulate matter inhaled from indoor air pollution from household solid fuels [2]. But in urban areas due to the absence of direct smoke from indoor coal burning the problems can be subtle and do not always produce easily recognized impacts on health. In urban states, the effects are majorly constrained to chronic problems. Two NIEHS-funded studies from the Columbia Center for Children's Environmental Health (CCCEH) at the Columbia University Mailman School of Public Health have showed that children exposed to piperonyl butoxide (PBO) in the womb had an increased risk of non-infectious cough that is they are more likely to have a cough, unrelated to a cold or the flu, when they were between 5 and 6 years old. The findings provide evidence that children's respiratory systems are susceptible to damage from contaminates during the prenatal period. Another research team performed a prospective epidemiologic study on 1,759 children from 12 communities in Southern California. The communities had a wide-range of exposures to air pollutants including particulate matter, acid aerosols, ozone, and nitrogen dioxide [7]. Lung function tests were performed annually for 8 years. Over the 8-year period, decreases in a measurement of lung function known as forced expiratory volume (FEV) were observed. Exposure to these pollutants was associated with statistically and, more importantly, clinically significant deficits in FEV. For example, the risk of low FEV was almost 5 times higher at the highest level of particulate matter exposure than at the lowest level. In another study a significant association between prenatal exposure to polycyclic aromatic hydrocarbons (PAHs) and attention deficit and symptoms of anxiety and depression among children ages 6-7 was found in the CCCEH longitudinal cohort study [8].

2) RESULTS AND DISCUSSION

2.1 Prenatal Airborne Polycyclic Aromatic Hydrocarbon Exposure and Child IQ at Age 5 Years

American Academy of Pediatrics (April 2013) determined a relationship between Polycyclic Aromatic Hydrocarbon exposures and a strong interdependence between exposure and poor health of the child IQ [1]. The Polycyclic aromatic hydrocarbons (PAHs) are released to air during incomplete combustion and/or pyrolysis of fossil fuel, tobacco, and other organic material. Although exposure is ubiquitous, high-risk groups both for disproportionate exposure to air pollution and for adverse health and developmental outcomes is represented by urban minority populations. In fact, 100% of the mothers in the Columbia Center for Children's Environmental Health (CCCEH) cohort had detectable levels of PAHs in prenatal personal air samples, and 40% reported environmental tobacco smoke (ETS) exposure during pregnancy. Among the 249 children 5 years of age, prenatal PAH exposure levels ranged from 0.49 ng/m^3 to 34.48 ng/m^3. A total of 140 (56.2%) of the 249 children were classified as having high PAH exposure (2.26 ng/m^3), with 2.26 ng/m^3 being the median for the entire cohort.

As shown in **Table 1**, the inverse associations between high/low PAH exposure and full-scale and verbal IQ scores remained significant after adjustment was done for covariates. The association with performance IQ was inverse but it was not significant. The associations between logarithmically transformed, continuous, PAH levels as the independent variable and IQ also were significant for full-scale IQ and verbal IQ. As discussed above, results from this cohort indicated that exposure to PAH air pollutants during pregnancy is a risk factor for developmental delay at age 3, which was also identified with the Bayley Scales of Infant

Development. The present analysis shows continued effects of prenatal PAH exposure on child IQ at age 5. After adjustment for potential confounders, full-scale and verbal IQ scores of the high- and low-exposure groups differed by 4.31 points and 4.67 points, respectively. The present findings are of concern because verbal and full-scale IQ scores measured with the WPPSI (Wechsler Preschool and Primary Scale of Intelligence) during the preschool period were shown to be predictive of subsequent elementary school performance in a range of populations.

2.2 The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age

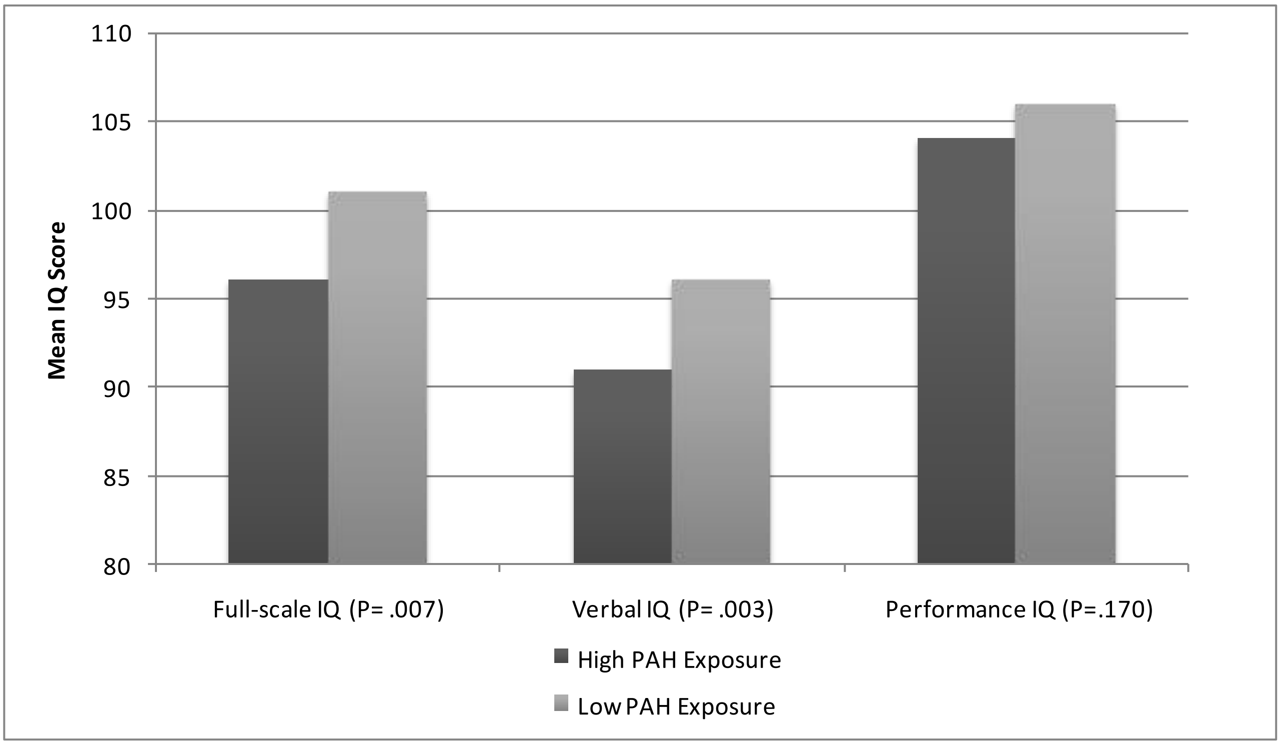
There is substantial evidence to show that air pollution has chronic, adverse effects on pulmonary development in children. In 1993, the Children's Health Study recruited 1759 children (average age, 10 years) from elementary schools in 12 southern California communities to investigate the long-term effects of air pollution on children's respiratory health [9]. The data for the study which was on pulmonary function were obtained by trained field technicians, who travelled to study schools annually from the spring of 1993 through the spring of 2001 to perform maximal-effort spirometric testing of the children. The three main measures of pulmonary function that are analyzed in the study are: forced vital capacity (FVC), forced expiratory volume in the first second (FEV), and maximal mid-expiratory flow rate (MMEF). Questions administered at the time of annual pulmonary-function testing were used to update information on asthma status, personal smoking status, and exposure to environmental tobacco smoke. In addition to examining the growth in lung function over the eight-year period, study was done on the FEV measurements obtained in 746 subjects to determine whether exposure to air pollution was associated with clinically significant deficits in attained FEV. A low

Table 1: Associations Between Prenatal PAH Exposure and Children's Full-Scale IQ, Verbal IQ and Performance IQ

	Full Scale IQ		Verbal IQ		Performance IQ	
	β	P	β	P	β	P
PAH exposure (high /low)	-4.307	.007	-4.668	.003	-2.369	.170
ETS exposure	1.736	.289	1.803	.265	1.609	.368
Gender	3.632	.021	4.695	.002	2.354	.168
Maternal Education	5.233	.002	4.510	.007	4.969	.007
Ethnicity	1.440	.373	6.74	.000	.121	.453

Source: Perera. 2012

Figure 1: Differences in full-scale, verbal and performance IQ scores associated with high levels of prenatal PAH exposure.



Source: Perera. 2012

FEV was defined as an attained FEV below 80 percent of the predicted value which is a common criterion used in clinical settings to identify persons who are at increased risk for adverse respiratory conditions. Among the girls, the average FEV increased from 1988 ml at the age of 10 years to 3332 ml at the age of 18 years, yielding an average growth in FEV of 1344 ml over the eight-year period.

The corresponding averages in boys were 2082 ml and 4464 ml, yielding an average growth in FEV of 2382 ml over the eight-year period. Similar patterns of growth over the eight-year period were observed for FVC and MMEF **(Table 2).**

The differences which were estimated in the growth of FEV, FVC, and MMEF during the eight-year period with respect to all pollutants are summarized in **Table 3**. Deficits in the growth of FEV and FVC were observed for all pollutants, and deficits in the growth of MMEF were observed for all but ozone, with several combinations of outcome variables and pollutants attaining statistical significance.

The study resulted in providing robust evidence that lung development, as measured by the growth in FVC, FEV, and MMEF from the ages of 10 to 18 years, is reduced in children exposed to higher levels of ambient air pollution and is the major result of this study. The strongest associations were observed between FEV and a correlated set of pollutants, specifically nitrogen dioxide, acid vapour, and elemental carbon. The effects which these pollutants have on FEV were similar in boys and girls and remained significant among children with no history of asthma and among those with no history of smoking, suggesting that most children are susceptible to the chronic respiratory effects of breathing polluted air. The effects of air pollution on the growth in lung function was observed and it was found that its magnitude during this age interval was similar to those that have been reported for exposure to maternal smoking and smaller than those reported for the effects of personal smoking.

Table 2: Mean Levels of Growth in Pulmonary Function during the Eight-Year Study Period, from 1993 to 2001.

Pulmonary-Function Measure	Girls			Boys		
	Age of 10 yr	Age of 18 yr	Average 8-yr growth	Age of 10 yr	Age of 18 yr	Average 8-yr growth
FVC (mL)	2262	3790	1528	2427	5202	2775
FEV (mL)	1988	3332	1344	2082	4464	2382
MMEF (mL/sec)	2311	3739	1428	2287	4709	2422

Source: Gauderman, 351 (11): 1-11.

Table 3: Difference in Average Growth in Lung Function over the Eight-Year Study Period from the Least to the Most Polluted Community.

Pollutant	**FVC**		**FEV**		**MMEF**	
	Difference (95% Cl) mL	P Value	Difference (95% Cl) mL	P Value	Difference (95% Cl) mL	P Value
O_3						
10 am – 6 pm	-50.6	0.37	-22.8	0.62	85.6	0.40
1-Hour Maximal level	-70.3	0.20	-44.5	0.32	45.7	0.65
NO_2	-95.0	0.05	-101.4	0.005	-211.0	0.02
Acid vapour	-105.2	0.03	-105.8	0.004	-165.0	0.07
PM_{10}	-60.2	0.33	-82.1	0.08	-154.2	0.16
$PM_{2.5}$	-60.1	0.24	-79.7	0.04	-168.9	0.06
Elemental Carbon	-77.7	0.08	-87.9	0.007	-165.5	0.04
Organic Carbon	-58.6	0.37	-86.2	0.08	-151.2	0.19

Source: Gauderman, 351 (11): 1-11.

2.3 Associated diseases with indoor air pollution in the rural households in India

Field surveys revealed that most of the rural households (almost 97 per cent) used traditional fuels (fuel wood, dung, crop residues, coal, kerosene) along with traditional stoves for cooking food [10]. Consequently, women are regularly exposed to high levels of pollutants emitted from cooking fuels during cooking. Though the specific effects on Indian children have not been researched yet still many cases of low birth weight and pre-natal mortality have been recorded, which directly links the effect on children with air pollution caused by traditional fuels and stoves (*chulhas)* in rural India. An examination of **Table 4** shows the indoor air pollution associated diseases (in percentages) in the rural households. In a survey conducted in Aligarh in 2010, nearly all the households reported exposure to heat for more than 2 hours per day and to smoke for more than 1 hour per day, as most of them (97 per cent) use biomass fuels/traditional stoves for cooking purpose. When these biomass fuels are burnt in inefficient *chulhas* they emit lot of smoke. More than half of the households (65 per cent) reported of living in *kutcha*/semi-*pucca* houses which absorb the emitted pollutants from the combustion of biomass fuels for longer duration. Of the total sample, 71 per cent reported of acute upper respiratory infection (AURI), 48 per cent of acute lower respiratory infection (ALRI), 47 per cent of low birth weight, 47 per cent of chronic obstructive pulmonary diseases (COPD), 15 per cent of prenatal mortality, 14 per cent of eye irritation and cataract, 13 per cent of asthma and 11 per cent of pulmonary tuberculosis.

Table 4: Indoor air pollution associated diseases (in percentages) in the rural households in Aligarh, India

Occurrence of associated diseases	Percentage of households affected
1. Acute upper respiratory infection	70.84
2. Acute lower respiratory infection	48.29
3. Low birth weight	47.15
4. Chronic obstructive pulmonary diseases	46.70
5. Pre natal mortality	15.49
6. Eye irritation and cataract	14.12
7. Asthma	12.98
8. Pulmonary tuberculosis	10.93

Source: Abha Lakshmi Singh. 2012.

3. CONCLUSION

On the basis of various research papers reviewed it can be concluded that environmental PAHs at levels encountered in the ambient air can affect child IQ scores adversely. And since IQ is an important predictor of consequent academic performance of a child the study of PAHs is a potential concern and further experiments must be carried on to confirm the results. Also, a reduced IQ may affect the overall mental health of the individual. Our observation of associations between air pollution and all three measures of lung function — FVC, FEV, and MMEF — suggest that there are certainly some unknown mechanisms which lead to reduced lung development when exposed to pollutants. People at higher risk are the rural children who are exposed to smoke for long hours because of the lack of good housing and infrastructure facilities. Given the magnitude of the observed effects and the importance of lung function as a determinant of morbidity and mortality during adulthood, continued emphasis on the identification of strategies for reducing levels of air pollutants is warranted especially in the Indian subcontinent.

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