Health Hazards of Ambient Air Pollution during Infancy and Childhood: An Overview

Madhulika Sharma*

Ambient air pollution is now recognized as an important problem affecting human health both nationally and worldwide. As revealed by the National Ambient Air Quality Monitoring Programme of Central Pollution Control Board, the level of the major air pollutants; particulate matter (PM), carbon monoxide, sulphur dioxide and nitrogen dioxide is continuously on rise in India due to an increase in emissions from industrial establishments, automobiles, domestic cooking and non-point sources like open refuse burning, unpaved roads, construction and building demolition activities. Many epidemiological studies have shown link between air pollution and health hazards like respiratory tract illness, asthma exacerbations and cardiovascular diseases. The studies have proved that infants and children are more vulnerable to the adverse effects of air pollution than are adults. In addition to the physical health problems, air pollution has also been found to affect children’s intellectual functioning, behavior and emotional states in certain studies of India and abroad. Exposure to lead and polychlorinated biphenyls (PCBs), two major persistent and biocumulative air toxins, have been found to be associated with behaviours similar to those of developmental disorders like autism and attention deficit hyperactivity disorder (ADHD), functional abnormalities, poor school performance and learning disabilities in children. However, there is need for greater scientific understanding of the spectrum of health effects of air pollution, especially in India.

[Keywords: Ambient air pollution, Health, Infants, Children]

1. Introduction

Rapid deterioration of the environment is becoming a serious cause of concern for the health of humans all over the world. Day to day increase in population in the
cities, intense anthropogenic activities are making the air we breathe more and more toxic. Industrial emissions, increasing number of vehicles, badly maintained roads, burning of waste in open and use of generators due to power cut-offs are the main sources of air pollutants in India. The polluted air of cities is posing serious threats to the health of the people residing in the near vicinity of industries, roads and commercial hubs. As per the 2016 Environmental Performance Index, more than 3.5 billion people, i.e., about half of the world’s population, are exposed to unsafe air quality which also includes 75% of India’s population. However, Indian air quality standard limits the safe exposure to particulate matter (PM$_{2.5}$) up to 40 µg/m$^3$ and a recent study reveals that 50% population living in 45% districts of India is exposed at PM$_{2.5}$ concentration beyond 40 µg/m$^3$ (Chaudhary, S. and Dey, S., 2016). According to Ambient Air Pollution Database, WHO (2016), India has 13 cities in worlds top 20 most polluted cities with Delhi leading the pack along with Patna, Gwalior, and Raipur respectively. Out of 1215 most polluted cities recorded, 133 were Indian with 31 in top 100 most polluted cities.

A large number of observational epidemiological studies of disease occurrence in the human populations, in-vitro and in-vivo studies of animals and humans have found association between the rising ambient air pollution and increased respiratory mucosal symptoms, exacerbation of asthma, chronic obstructive pulmonary disease (COPD) as well as cardiovascular diseases and mortality (World Health Organization, 2003 and Health Effect Institute, 2002).

Recent studies have proved that people exposed to toxic air pollutants at sufficient concentrations and durations may also have an increased chance of damage to the immune system, neurological, reproductive (e.g., reduced fertility) and developmental problems (USEPA, 2001). Infants and children are found to be one of the most susceptible groups towards the health hazards of air pollution. Air pollution has been linked to diseases and infections that kill around six lakhs children under five years of age per year (Rees, N., 2016). A study even shows that about 2.2 million school children in Delhi are growing up with irreversible lung damage which they will never recover (Ghosal, A & Chatterjee, P., 2015). The number of premature deaths due to outdoor air pollution is projected to increase from 3 million people globally in 2010 to a global total of 6 to 9 million people in 2060 (OECD). Total welfare losses due to air pollution in India amounted to more than 500 billion US$ (~8.5% of country’s GDP) in the year 2013 (381% increase from 1990) (Jain, D., 2016).

In the present paper, various air pollutants and their toxic effects on human body are being discussed. Various researches conducted to study the effects of air pollution on physical and mental health in India and abroad have been summarized. In the end certain suggestions for future researches in this direction are given. Such scientific studies on health effects of children may prove to be of great assistance to policy makers and health workers in making effective air pollution policies to ensure protection of infants and children’s health.
2. Toxic Air Pollutants and their Sources

Toxic air pollutants also known as hazardous air pollutants (HAPs) are those pollutants that are known or suspected to cause cancer or other serious health effects such as reproductive effects or birth defects or adverse environmental effects. United States Environmental Protection Agency (USEPA, 2000) has listed about 188 pollutants referred to as HAP. Particulate Matter (PM), SO$_2$, NO$_2$, benzene, volatile organic compounds (VOCs), ozone, lead are the major air pollutants measured by the Central Pollution Control Board (CPCB) under the National Ambient Air Quality Monitoring (NAAQM) programme in our country. These air pollutants are released mainly from combustion processes especially of diesel-powered engines, power generation, wood burning, crushing, grinding operations and other industrial activities (Table-1). Out of these air pollutants, particulate matter; inhalable and respirable particles of diameter less than 2.5 micron (PM$_{2.5}$) and of diameter less than 10 microns (PM$_{10}$) are considered to be the most hazardous for human health. They are a complex mixture of dry solid fragments, solid core with liquid coatings and small droplets of liquid. These tiny particles vary greatly in shape, size and chemical composition. They may constitute black carbon, sulphates, nitrates, minerals, dust etc.. Particulates are highly carcinogenic and have been classified in Group I Carcinogens because of their ability to penetrate deep into the lungs and bloodstreams (IARC).

The type of pollutants emitted in the air may vary from place to place depending on the sources and meteorological parameters like wind speed, wind direction, rainfall, relative humidity, temperature, barometric pressure etc. Some pollutants remain airborne or react in the atmosphere to produce other harmful substances. Ground level ozone is an example of a secondary pollutant formed by chemical reaction of volatile organic compounds and nitrogen oxides in the presence of sunlight. Other air pollutants deposit into and contaminate land and water. Children can be exposed to toxic air pollutants through contaminated air, water, soil, and food.

3. Entry of the Pollutants into the Human Body

Toxic air pollutants enter the body mainly through breathing. Toxic air pollutants can also be ingested through contaminated soil, food and water or absorbed through the skin. Once a pollutant enters the body, it can stay in the lungs, be exhaled or move into the blood from the lungs or from the digestive system or skin.

In the blood it is carried to all parts of the body. As it moves around the body, a pollutant can undergo chemical changes and trigger pro-inflammatory responses (Gonzalez- Flecha, 2004). Toxic air pollutants can cause health problems by interfering with normal body functions. Most commonly they change chemical reactions within individual cells, the building blocks of living things. These
changes can kill cells, impair cell function, or re-direct cell activity. The results can be damaged organs, birth defects when the cells of an unborn child are damaged, or cancer that develops when cells begin to grow at an uncontrolled rate. The mechanism involved in the cellular damage and various pathological conditions inside the body due to the toxic pollutants like PM has been very well discussed by Elisa Ghelfi (2011) of Department of Environmental Health, Boston, USA in her paper on ‘Air Pollution and Reactive Oxygen Species’. Free radicals and oxidative stress have been implicated in inflammatory response after exposure to particulate matter (PM) (Donaldson et al., 2005). Both organic and transition metals present in PM are able to generate free radicals. Free radicals are active molecules with an unpaired electron. In biological settings free radicals are potentially very dangerous since they can react indiscriminately with neighboring molecules in order to acquire one electron. This process of electron stealing leads to oxidation and often inactivation of target molecules and cellular damage. Excessive amounts of Reactive Oxygen Species (ROS) is referred to as oxidative stress and contributes to depletion of antioxidants, cause aberrant cell death and have been implicated in a variety of pathological events like cardiovascular diseases, inflammation and neurodegenerative diseases (Chen & Nadziejko, 2005).

Some toxic air pollutants such as lead, mercury, and dioxins degrade slowly or not at all. These pollutants may bioaccumulate in humans directly or through animals. Lead is mainly emitted through leaded petrol and industries. Industrial emissions, especially from coal-fired power plants, are the leading source of environmental mercury. Although the levels of airborne mercury may not be hazardous, mercury deposits into soil and surface waters and ultimately accumulates in fish which is further consumed by people (American Academy of Pediatrics, 2001).

In majority of the cases as the air pollutants are inhaled though the lungs, the initial symptoms of toxicity are respiratory problems like coughing, sneezing, breathing problem, dizziness etc. If the exposure to these air pollutants continues, it may affect other organ systems also in addition to respiratory system. The short term and long term clinical and subclinical effects of various pollutants on children are being discussed under physical and mental health hazards.

4. **Effects of Ambient Air Pollution on Physical Health of Infants and Children**

The effect of exposure to air pollutants can be studied from an early stage of prenatal development. The toxicity may lead to many physical problems like organ damage and dysfunctioning of organ systems during the prenatal periods. Later at the stages of infancy and childhood, the problems may be aggravated. There are many reasons given behind greater susceptibility of children as compared to the adults. Due to higher minute ventilation and higher levels of physical activity, the
exposure to the air pollutants is much more in children as compared to the adults. The breathing rate is also higher as compared to the adults. In a recent study it has been proved that children two years of age and under have ten times the risk of adults from exposure to toxins because infants take 45 breaths to 10 adult breaths (USEPA, 2001). Their lungs, airways and immune systems are weaker. Their skin is thinner and more permeable, and they have a larger surface area for absorption relative to weight. Similarly, the elderly people and the patients suffering from respiratory and heart diseases are also highly vulnerable to the toxic effects of these air pollutants. Even a small amount of toxic air pollutant may lead to health hazards.

The major air pollutants and their toxic effects on physical health of people including children have been briefly described below in table no.1. Depending on the level of exposure, these air pollutants may cause various physical health problems. The air pollutants may affect the respiratory, cardiovascular, ophthalmologic, dermatologic, neuropsychiatric, hematologic, immunologic, and reproductive systems. The molecular and cell toxicity may also induce a variety of cancers in the long term (Loomis D, Huang W, Chen G, 2014; Rodopoulou S, et al, 2014; Carugno M et al, 2016). In case of long term or chronic exposures they may even prove to be fatal.

**Table-1 : Major air pollutants and their short term and long term effects on physical health**

<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Major Sources of Emission</th>
<th>Short term Effects</th>
<th>Long term Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Matter (PM$<em>{10}$ &amp; PM$</em>{2.5}$)</td>
<td>Motor engines, industrial activities</td>
<td>Wheezing cough, dry mouth, breathing problems or decreased lung functions</td>
<td>Respiratory diseases like asthmatic bronchitis and COPD, heart disease like cardiopulmonary &amp; cardiac dysrhythmias, cancer</td>
</tr>
<tr>
<td>Carbon mono oxide</td>
<td>Burning coal, wood, motor engines, industrial activities</td>
<td>Headache, weakness, dizziness, nausea, vomiting</td>
<td>Cardiovascular diseases</td>
</tr>
<tr>
<td>Sulphur-di-oxide</td>
<td>Burning of fossil fuel, natural volcanic processes, industrial activities</td>
<td>Damages to the eyes (lacrimation and corneal opacity), mucous membranes, the skin (redness, and blisters), and respiratory tracts ; Bronchospasm, pulmonary edema, pneumonitis, and acute airway obstruction</td>
<td>Respiratory irritation and dysfunction, cardiovascular diseases</td>
</tr>
</tbody>
</table>
5. **Effects of Ambient Air Pollution on Mental Health/ Neuropsychological Health of Infants and Children**

As it has already been discussed by Gonzalez-Flecha (2004) and Elisa Ghelfi (2011), the air pollutants may damage various organ systems of the body systems like respiratory, circulatory systems and impair their functioning. Similarly, human epidemiological studies have shown that air pollution may negatively affect the Central Nervous System (CNS) and contribute to the developmental disorders like ASD, ADHD among children. Decreased cognitive function has also been reported in children, adults and the elderly. Olfactory dysfunction, auditory deficits, depressive symptoms and other adverse neuropsychological effects have also been reported.

Primary mechanisms of air pollution neurotoxicity are related to oxidative stress and neuroinflammation which are also involved in the etiopathology of various neurodegenerative diseases. The nervous system, particularly the central nervous system (CNS), is vulnerable to oxidative stress because it has high metabolic demands, high energy use, widespread axon and dendrite networks, high cellular content of lipids and proteins, and low levels of endogenous scavengers, such as vitamin C and superoxide dismutase, which, to some extent, may be due to the CNS being isolated (Pajovic SB et al, 2003). The CNS in a child could be especially susceptible to oxidative stress from environmental toxicants because of its immature blood brain barrier and a wide range of exposures. White matter lesions have also been reported due to the toxic effects of air pollutants. A clear connection has been found between these lesions and decreases in brain

<table>
<thead>
<tr>
<th>Substance</th>
<th>Sources</th>
<th>Effects</th>
<th>Health Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen-di-oxide</td>
<td>Mainly motor engines</td>
<td>Coughing and wheezing, eyes, nose or throat irritations, headache, dyspnea, chest pain, diaphoresis, fever, bronchospasm, and pulmonary edema</td>
<td>Respiratory diseases</td>
</tr>
<tr>
<td>Lead</td>
<td>Industrial activities; smelters, battery plants, irrigation water wells and wastewaters, leaded petrol</td>
<td>High blood pressure, infertility, digestive and renal dysfunctions, and muscle and joint pain, abdominal pain, anemia, aggression, constipation, headaches, irritability, reduced sensations, and sleep disorders</td>
<td>Damage to cardiovascular, renal, reproductive and nervous systems</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons (PAH)</td>
<td>Fuel combustion, wood fires, motor engines</td>
<td>Respiratory dysfunctions</td>
<td>Damage to CNS, cancer</td>
</tr>
</tbody>
</table>

**Source**: Ghorani-Azam, Adel et al, 2016
volume, loss of memory, vision and cognitive impairment (De Groot, De Leeuw et al, 2002). On the basis of extensive review of literature the neuropsychological problems specific to various toxic air pollutants have been listed in the table-2.

### Table-2: Major air pollutants and their Neuropsychological Effects on children

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Air Pollutant</th>
<th>Neuropsychological Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Particulate Matter (PM$<em>{2.5}$ &amp; PM$</em>{10}$)</td>
<td>Delayed psychomotor development, Decreased verbal and nonverbal intelligence, decreased memory, Autistic Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD)</td>
</tr>
<tr>
<td>2.</td>
<td>Paracyclic Aromatic Hydrocarbons (PAH)</td>
<td>Behaviour problems, lower visual motor abilities, delayed psychomotor development, reduced verbal intelligence, ADHD</td>
</tr>
<tr>
<td>3.</td>
<td>Nitrogen di oxide (NO$_2$)</td>
<td>Delayed psychomotor development, reduced executive function (attention and working memory), ASD</td>
</tr>
<tr>
<td>4.</td>
<td>Sulphur di oxide (SO$_2$)</td>
<td>Delayed psychomotor development, ASD</td>
</tr>
<tr>
<td>5.</td>
<td>Lead (Pb)</td>
<td>Reduced verbal and nonverbal intelligence, ASD</td>
</tr>
<tr>
<td>6.</td>
<td>Ground level ozone (O$_3$)</td>
<td>Lowered global and verbal development scores, ASD</td>
</tr>
</tbody>
</table>


As far as Indian studies are concerned, mental health is a nascent field of research. However, there are few studies conducted in India which throw light on the effect of hazardous air pollutants on nervous system functioning during various age groups (Gupta and Rastogi, 1989; Saxena and Saxena, 1988). A study by Sinha, S.P. (1995) examines and compares the neurotoxic effects of lead on the psychomotor behaviour of 960 school going children (9-14 years) of four areas; roadside area, industrial area, commercial area and remote residential area of Agra city.

### 6. Conclusion

There is a growing evidence of impact of hazardous air pollutants on the physical and mental health of infants and children. However, there are a few aspects of research on health hazards of air pollutants on children which need to be taken care of. Firstly, majority of the studies in this field follow cross-sectional approach. The approach of studies in this area should focus more on longitudinal approach as proper feedback could be obtained from a continuous 10-11 year old study of the same subjects. There is a need for more studies on cumulative effect of various pollutants found in ambient air pollutants rather than focusing on individual pollutants like PM, SO$_2$, NO$_2$ etc. These studies should have humans as subjects and not the animals exclusively. Studies should incorporate personal monitoring of air pollutants inhaled by the children for studying their day to day exposure to air pollution. In the case of neuropsychological testing, the tests should be more culturally sensitive for use in various countries. Lastly, researchers from various fields like health professionals, pediatricians, behavioral scientists, psychologist and environmentalists need to collaborate with each other for an in-depth understanding of the broad spectrum of health hazards of air pollution.
References


International Agency for Research on Cancer, Evaluation, IARC Monographs - 109, IARC.


OECD, Policy Highlights, The economic consequences of outdoor air pollution, Organisation for Economic Co-operation and Development


WHO, Ambient Air Pollution Database, May 2016 available: http://www.who.int/phe/health_topics/outdoorair/databases/WHO_AAP_database_May2016_v3web.xlsx?ua=1