Chapter V: Air Quality

A. Overview

The air that we breathe daily is comprised of 21% oxygen and 78% nitrogen, with the remainder consisting of trace amounts of rare gases. Air pollution causes some gases in the atmosphere to exist at higher than normal conditions, and can be seriously harmful to human health. Examples of these include: nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO), particulate matter (PM), photochemical oxidants (e.g., ozone) and lead (Pb), along with a variety of airborne heavy metals and volatile organic compounds (VOCs).

Air pollution can occur as a result of natural conditions, such as ash from volcanic explosions, sand storms, or forest fires. Natural geomorphic terrain, such as low valleys surrounded by mountains, temperature, and wind speed can also exacerbate already polluted surroundings in a region. More serious, however, are the anthropogenic, or human, causes of air pollution that are directly linked to energy consumption, industrial emissions and vehicular exhausts in heavily congested urban areas. It is often a combination of both natural factors as well as human activities that lead to highly unhealthy conditions in air quality (for more details, refer to Appendix A.)

B. Impact of Air Pollutants on Human Health

Air pollution has a variety of negative effects not only on the environment, but on human health as well. In addition to impairing lung and respiratory systems, inhaled air pollutants are absorbed by circulating blood and dispersed throughout the rest of the body. Emissions of sulfur oxides (SOx) and nitrogen oxides (NOx), formed from combustion of fossil fuels, cause acid rain that occurs over long distances reaching up to 1,000 kilometers from the emission source. Acid deposition affects the chemical balance of soils and can cause damaging leaching of minerals and nutrients crucial to the growth of trees and plants. Furthermore, residue from air pollutants can be found on plants and water consumed by humans, thereby contributing to further levels of harmful exposure through ingestion. Automobiles, industrial activity, and electrical plants are the main sources in the production of harmful gases, such as sulfur oxides, nitrogen oxides, and carbon monoxide (CO).

It should be noted that a recent White House study (September 2003) by the Office of Management and Budget (OMB) states that the benefits to human health from reducing air pollution from manmade sources far outweigh the costs of regulating it. The report concluded that the health and social benefits of enforcing tough new clean-air regulations during the past decade within the U.S. were five to seven times greater in economic terms than were the costs of complying with the rules. The findings overturn a previous report that officials now say was defective, and provide the most comprehensive federal study ever of the cost and benefits of regulatory decision-making.

Outdoor and Indoor Air Pollution [8]

Air pollution continues to be a major environmental problem in many regions of the world today. In the past two to three decades, with increasing urbanization and industrialization in developing countries, the steady decline of air quality poses a significant threat to health for large segments of human populations. In many urban areas of Asia, Latin America and Africa, deteriorating air quality has been associated with rapidly rising population growth and increased use of motor vehicles, coupled with inadequately regulated emissions of air pollutants from industrial plants and power generating facilities. Annually, air pollution accounts for an estimated 3 million deaths, which is about 5% of the 55 million deaths that occur worldwide each year.

The World Health Organization (WHO) estimates that as many as 1.4 billion urban residents globally are exposed to outdoor polluted air that exceeds WHO air quality guidelines, including guidelines for sulfur dioxide, nitrogen dioxide and particulate matter. In addition, in many heavily populated regions, such as China and India, indoor air pollution poses an even greater threat to human health, especially among women and children who tend to spend more time at home. Indoor air pollution often occurs when residents living in poorly ventilated homes are exposed to excessive smoke and a variety of airborne pollutants that arise from fuel burning sources, such as cook-stoves and other heat producing devices. It is estimated that some 3.5 billion rural residents globally are exposed to high levels of indoor air pollutants, which have been designated by the World Bank as one of the four most critical public health problems worldwide (the other three are waterborne diseases, HIV/AIDS and tobacco use and smoking.)

8 Excerpted from: Ahmed, A. Karim. *op. cit.*

In the past several decades, air quality has generally improved in many developed countries in North America and Europe. However, the continuing elevated levels of certain air pollutants in urban and industrial areas still remain a major public health problem in developed regions, especially among young children, the elderly and other vulnerable segments of the population. For instance, in the United States, air pollution continues to account for approximately 60,000 deaths each year, caused principally by gaseous and particulate emissions from motor vehicles and other fossil fuel burning sources. In developed countries, greater attention has been paid by regulatory agencies in recent years to reduce the concentration of fine particulate matter and photochemical oxidants in the atmosphere, which cause a number of serious acute and chronic respiratory diseases. Among the major sources of high levels of airborne fine particulates (less than 2.5 micrometers in diameter) in developed countries are electric power generating plants, metal refining processes and diesel-engine motor vehicles.

C. Outdoor Air Pollutants

(i) Carbon Monoxide (CO)

Automobile or industrial plants that combust materials of biological origin such as wood, coal, and oil incompletely decompose organic carbon present in these fuels into carbon monoxide. Availability of adequate oxygen is thus required for most materials to burn completely into carbon dioxide (CO_2)—the more oxygen available, the more efficiently the fuel burns. For these reasons, CO emissions can be reduced by increasing the level of oxygen available during the combustion process to ensure that the fuel is properly combusted before being expelled as partially decomposed smoke, while producing high concentrations of carbon monoxide. The purpose of using catalytic converters in automobile tailpipes is to mix more oxygen into the fuel tank to ensure that gasoline is more efficiently burned, producing lower levels of CO in the exhaust. Health Effects of odorless and colorless carbon monoxide include hypoxia, dizziness, neurological deficits, and neurobehavioral changes, among others symptoms.

(ii) Nitrogen Dioxide and Ozone

Nitrogen dioxide (NO_2), as a component of nitrogen oxides (NOx), is emitted from anthropogenic sources, such as electric power generation, industrial processing and automobile exhausts. NO_2 is, however, not only a primary pollutant in itself, but produces another airborne pollutant, ozone (O_3) (a major component of photochemical oxidants), making it a secondary air pollutant as well. When NO_2 enters the lower atmosphere (troposphere) it breaks down photo-chemically under ultraviolet light to form nitrogen oxide (NO) and atomic oxygen (O). The atomic oxygen reacts with oxygen molecules (O_2) already present in the atmosphere to form ozone (O_3), a highly toxic substance that is harmful to human health. *Health Effects* of nitrogen dioxide include weakened respiratory systems and lung function, chronic cough, bronchitis and conjunctivitis. Short-term acute effects of ozone include increased airway responsiveness and inflammation, aggravation of pre-existing respiratory diseases such as asthma, and increased incidences in respiratory distress.

(iii) Sulfur Dioxide (SO2)

Sulfur dioxide (SO_2), a component of sulfur oxides (SOx), is also a primary and secondary pollutant. Further oxidization of SO_2 leads to sulfur trioxide (SO_3), which reacts with water vapor to form sulfuric acid (H_2SO4), an important contributor to atmospheric fine particle acid aerosols (acid rain). The combustion of coal for domestic heating and cooking as well as industrial purposes, such as coal fired power plants, contributes significantly to sulfur dioxide in the air. Diesel fuel used in trucks and buses is a major problem, as diesel fuel contains high amounts of sulfur. Not only is the sulfur from diesel fuel in itself highly toxic, but it also inhibits other automotive filtering systems, such as particulate traps and catalysts, from properly functioning. [9] *Health Effects* of sulfur dioxide include aggravation of illnesses in those with already weakened respiratory function, such as asthmatics, who are particularly susceptible to the adverse impacts of this air pollutant.

9 National Resources Defense Council (NRDC). *Reducing Diesel Sulfur Levels to Reduce Urban Pollution*. Available online at: http://www.nrdc.org/air/transportation/psulfur.asp.

(iv) Lead (Pb)

Lead has been used throughout modern history for a broad range of purposes, ranging from cosmetic products and paints to water piping. However, its harmful effects on human populations have only been determined in the past fifty years. Historians have now postulated that the fall of the Roman Empire can be traced to the high amounts of lead used in drinking vessels and other materials in certain sectors of their society. Today, one of the greatest sources of lead in the air occurs as a by-product of leaded gasoline used in automobiles. Lead is used to increase the octane rating in gasoline as an anti-knocking agent. [10] In the past two decades, most developed countries in North America and Western Europe have phased out lead additives in gasoline while implementing sodium-based additives capable of achieving the same anti-knock goals. Many developing regions of the world, unfortunately, still include lead additives in their gasoline. *Health Effects* of lead are especially severe on young children, as it is capable of affecting their nervous systems that are still in the process of development, and can lead to long-term cognitive difficulties. Lead exposure in adults as well as children can lead to central nervous problems, increased blood pressure, mental deficits, brain damage and death.

(v) Particulate Matter (PM)

Particulate matter can occur either from naturally occurring sources in the air, such as volcanic ash, dust, and plant materials, or as a product of human activities. Particulate matter occurring from human activities such as combustion of fossil fuels in industry (through secondary conversion of sulfur oxides into acid aerosols) and from motor vehicles (particularly from diesel-powered engines), are generally lighter and finer than those originating from natural sources. Fine particulate matter (less than 2 micrometers in diameter) is especially dangerous to human health as it is small enough to pass through the respiratory system's clearing mechanism which is capable of blocking only coarser particles, allowing it to penetrate deeply into the lung where it can remain indefinitely. In addition, fine particles are capable of remaining in the atmosphere for relatively long periods of time and can move over large distances, resulting in acid precipitation into lakes and streams. *Health effects* of particulate matter include shortness of breath, bronchitis, asthma, and pre-mature deaths.[11]

D. Indoor air pollution

Although air pollution is most commonly associated as an outdoor concern, many regions of the world have significant health risks associated with indoor air quality. Many developing countries are especially at risk from the effects of indoor air pollution, as the highest air pollution exposures occur inside homes in these regions. Indoor air pollution is a major contributor to mortality rates in developing countries, comprising 84 percent of the 3 million deaths due to air pollution worldwide. [12] Many households in developing countries, such as China and India, rely on biomass and coal in open fires or stoves for their indoor heating and cooking needs, often without proper ventilation. When air pollution occurs in the home environment it can be especially dangerous for women and children who spend most of their time indoors, where airborne substances are released in proximity to their living quarters. In addition, toxic air hazards in the workplace can have similar consequences as those found in the home, as exposures to air pollutants are much higher indoors than in the outdoor environment, where the airborne substances may disperse more readily.

E. Human Exposure to Air Pollutants

(i) General Considerations

The ability to anticipate the daily habits of an area's inhabitants is important in terms of understanding what type of air pollution they are most at risk. Urban populations have different exposure problems than those living in rural areas, as do populations in temperate zones versus those living in cold, arctic conditions. Urban populations, for example, are closest to sources of ambient outdoor air pollution, yet they also tend to spend most of their time indoors, both at work and home. Climate and geographic location will determine how often an individual is likely to spend outdoors or indoors with the windows open. Socio-economic status is of importance, especially with the

10 World Bank Group. (1998). *Removal of Lead from Gasoline: Technical Considerations. Pollution Prevention and Abatement Handbook*. Washington, DC: World Bank Group.

11 Ahmed, A. Karim (2003). *Ob Cit.*

12 World Health Organization (WHO). 2001. *Strategy on Air Quality and Health*. Geneva: WHO.

poorest segments of the population, who live in congested urban areas and are most at risk from exposure to air pollutants.

Another factor is that the local concentrations of airborne pollutant depend on the sources and rates of dispersion. Variations from day to day in air quality are more a result of meteorological conditions than the intensity of source emissions. For example, air pollutant dispersal is minimal when cold, still weather conditions exist, however dispersal rates will increase with strong winds and frequency of ground turbulence.

Exposure to air pollution is measured as a product of concentration of the pollutant and the duration of exposure in a given region. The amount of time spent indoors or outdoors should be considered when determining exposure risks to air pollutants. For instance, most urban people spend a large fraction of their days indoors and are thus more exposed to indoor air pollution, while those living in warmer, more rural climates spend most of their time outdoors.

(ii) Vulnerability of Children, Elderly and Chronically Sick

Those most at risk to the adverse effects of air pollution are children, the elderly, those with an already weakened respiratory system, asthmatics, and those who are exposed to high concentration of air pollutants for extended time periods. The more economically disadvantaged sectors of society are also those that suffer most from living in degraded environmental conditions. Generally speaking, the severity of risk depends on a combination of factors: the source of air pollution, physical and chemical characteristics of the pollutant, the overall extent of exposure, and the availability of health care within immediate access.

(iii) Data Collection—Choice of Air Quality Indicators

Monitoring of harmful airborne substances is a necessary prerequisite to regulatory control of air pollution. Such monitoring systems should be carried out at various locations and over extended periods, since the airborne concentrations of harmful gases and particulate matter vary with distance and time. If air concentration levels in different countries are to be compared, a common system of comparison is crucial. The WHO uses air concentration units in terms of 'mass per unit volume' given as milligrams per meter cubed (mg/m3). This system is applicable to both airborne gases and particles whereas the volume-mixing ratio, i.e. parts per million or billion (ppm or ppb), is applicable only to atmospheric gases.

The main sources of information on air pollution in developing countries is generally derived from WHO's Air Management Information System (AMIS), which is based on voluntary reporting of air concentration data in the municipalities and urban centers of WHO member states.

The three most commonly measured pollutants are particulate matter (PM, reported as Total Suspended Particles, TSP or as PM10), nitrogen oxides (NOx), and sulfur oxides (SOx). Other harmful air pollutants (e.g., ozone, lead and carbon monoxide) are not widely measured and therefore data on these are often not available, or if available they may not be comparable from region to region. For these reasons, "surrogate" measures of the air pollutants such as lead exhausts from automobiles (e.g., indirectly measured as the ratio of unleaded/leaded gasoline available on the market) have been employed as alternate indicators and benchmarks in many regions of the world.

F. Recommended Environmental Indicators and Benchmarks of Air Quality

Basis for Selection:

One set of recommended primary indicators is based on human exposure to airborne concentration of three widely occurring air pollutants in the urban environment, namely nitrogen oxides, sulfur oxides and particulate matter. At present, these three air pollutants are monitored by regulatory agencies in most regions of the world, including in many cities and urban centers of developing countries. Thus, it is likely that data on the air concentration levels of one or more of these airborne pollutants are accessible from official government sources. Moreover, it is possible to carry out multi-year trend analysis of the extent of outdoor air pollution in a community where monitoring of these air pollutants has been being carried out over a period of time. In addition, development of primary indicators on air quality include obtaining data on the prevalence of the population with acute respiratory infection and chronic obstructive pulmonary diseases, since these ailments caused by bacterial and viral agents are often exacerbated by air pollutants found in a degraded environment. Finally, development of primary air quality indicators should attempt at establishing the percent of children below five years that are potentially exposed to high airborne lead levels in a community or region.

In many developing regions, where data on primary environmental health indicators may be missing or difficult to obtain, a number of secondary indicators are recommended that could provide indirect, but nevertheless adequate interim assessment of the impact of degraded air quality on a community. As an indirect measurement of nitrogen oxides arising from motor vehicles in urban areas, the percent of cars, trucks and buses with catalytic converters, which control the tail pipe emission of nitrogen dioxides, can serve as a surrogate air quality indicator or a policy-mandated benchmark. Similarly, determining the percent of sales of unleaded gasoline in a country or region could serve as a surrogate indicator or benchmark that assesses progress made in decreasing the impact of airborne lead on the health and well-being of young children in a community. Another indirect measurement of urban air quality in both developed and developing regions is determining the percent of diesel-free motor vehicles on the road, since diesel engines in general emit a high proportion of fine particulate matter into the atmosphere. The percent of the highly polluting two-stroke engines in auto rickshaws and motorized tricycles in many cities and towns of developing countries can serve as an indirect measure of urban air pollution, especially where their use is universally prevalent. Another surrogate measurement of urban and industrial air pollution is the determination of the percent of combustion sources (industrial, commercial, residential) that use coal as their primary fossil fuel, which in many unregulated or poorly monitored regions of the world is a major air emission source of sulfur oxides and particulate matter. As a complementary and inverse surrogate measurement of air pollution from industrial, commercial and residential sources is determining the percent of combustion units in a region using natural gas as an alternative cleaner burning fossil fuel.

In the development of tertiary outdoor air quality indicators and benchmarks, data on the distance and amount of time spent by an average commuter traveling to work in an urban region could provide significant information of potential motor vehicle related air pollution in a community. Similarly, the percent of an urban population using mass transportation or non-motorized means to travel to work can also provide a useful indicator or benchmark on the state of outdoor air quality of a region. For assessing indoor air pollution in many urban and rural areas of both developed and developing regions, development of two tertiary indicators or benchmarks are recommended: (i) percent of household using clean cooking stoves or heating fuel sources, which produce significantly reduced amount of particulate matter indoors, (ii) percent of workplaces and households with adequate ventilation, which assists in reducing exposure of workers, adults and young children to a variety of indoor air pollutants.

Summary of Recommended Indicators and Benchmarks:

(i) Primary Indicators

- Ambient Air Concentration of Nitrogen Oxides (NOx)
- Ambient Air Concentration of Sulfur Oxides (SOx)
- Ambient Air Concentration of Particulate Matter, PM (TSP or PM10)
- Prevalence of Population with Acute Respiratory Infection
- Prevalence of Population with Chronic Obstructive Pulmonary Disease (COPD)
- Percent of Children Below Five Years with Potential High Lead Exposure

(ii) Secondary Indicators

- Percent per Automobile Fleet with Catalytic Converters (nitrogen dioxide exposure)
- Percent of Unleaded Gasoline Available on the Market (lead exposure)
- Percent of Cars, Trucks, Buses with Diesel-free Engines (particulate matter exposure)
- Percent of Motorized Vehicles with Two-stroke Engines (air pollutant exposure)
- Percent of Industrial, Commercial and Residential Use of Coal (sulfur oxides, particulate matter)
- Percent of Industrial, Commercial and Residential Use of Natural Gas

(iii) Tertiary Indicators

- (Outdoor) Average Commuting Time and Distance
- (Outdoor) Percent of Urban Population that Uses Mass Transit
- (Outdoor) Percent of Urban Population Using Non-Motorized Transport
- (Indoor) Percent of Households Using Clean Cooking Stoves and Heating Fuel
- (Indoor) Percent of Workplaces and Households with Adequate Ventilation

(iv) Modifying Factors

- Rate of Urban Growth
- Geographic Location and Climate Type
- Population Density