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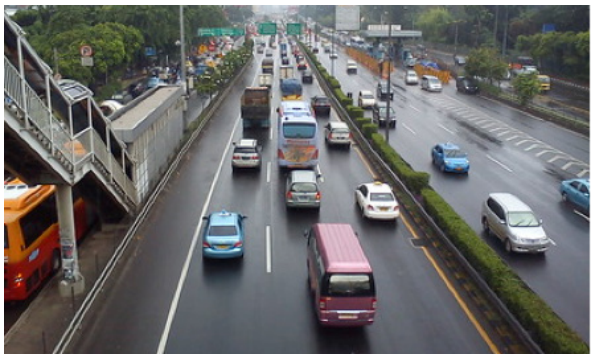
QUICK REFERENCE GUIDE

HEAT AND URBAN ENVIRONMENTAL ISSUES
AIR POLLUTION

OVERVIEW



Source: Afif, 2011

According to the Ambient Air Pollution database of the World Health Organization (WHO), almost nine out of ten people living in urban areas are affected by air pollution. Globally, air pollution is already a well-known public health risk factor; exposure to air pollution is the ninth leading risk for mortality worldwide, and it is responsible for 4.2 million deaths each year. Approximately 91 percent of these premature deaths occur in low- and middle-income countries, with the greatest number in South, East, and Southeast Asia. This risk is greater in urban areas where air quality is generally lower due to greater transportation, industrial and commercial emissions (e.g., road transport, power plants, fuel combustion, etc.). There is concern that climate variability and change could affect the morbidity and mortality associated with elevated concentrations of air pollutants, especially particulate matter (PM). (1, 18, 27, 30, 42)

Over the past 50 years, hot days, hot nights, and heatwaves have become more frequent. Global average temperatures are expected to increase significantly by the 2050s, with particularly large increases in cities. Among the most vulnerable are developing countries in the tropics, where projections for warming temperatures in urban areas will likely influence and increase air pollution levels, dispersion and concentration. (32)

Key Impacts

PM — **PARTICULATE MATTER (PM10, PM2.5)**
Sunlight increases the formation of PM
Increased absorption of radiation
Poses the greatest risks to human health

NO_2 — **NITROGEN DIOXIDE**
Increased heat and sunlight lead to higher NO2
Exacerbates asthma and bronchitis symptoms
Increases the risk of heart attack

SO_2 — **SULFUR DIOXIDE**
Increased heat increases SO2 levels
Increases the risk of hospitalization and death due to COPD, heart attacks and asthma

O_3 — **GROUND-LEVEL OZONE**
Increased heat and sunlight increases ozone
Increases hospitalizations and deaths due to COPD and asthma

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This document was prepared under the Adaptation Thought Leadership and Assessments (ATLAS) Task Order No. AID-OAA-I-14-00013 and is meant to provide a brief overview of heat's effect on urban environmental issues. The key resources at the end of the document provide more in-depth analysis. The contents of this report do not necessarily reflect the views of USAID.

This convergence of higher temperatures and increased air pollution levels and concentrations will challenge city officials, particularly to manage the effects on human health, such as an increased risk of morbidity and mortality associated with respiratory and cardiovascular conditions (e.g., chronic obstructive pulmonary disease [COPD]).

HEAT, OUTDOOR AIR POLLUTANTS AND HEALTH

Heatwaves are generally associated with poor air quality, and the correlation of exposure to air pollutants and heat increases the burden of both cardiovascular and respiratory diseases. As such, there is concern that projected increases in temperatures and heatwaves will increase ambient air pollution and impact human health. (29, 33, 42)

The pollutants with the strongest evidence for public health concern are particulate matter, ground-level ozone, nitrogen dioxide and sulfur dioxide. All four pollutants are inhalable, and as such, impact the cardiovascular and respiratory systems of urban residents. The following sections explore each of these pollutants individually, the impacts of heat on each pollutant and the consequences for health. (2, 42, 43)

PM PARTICULATE MATTER

Particulate matter, commonly referred to as "soot," is an inhalable, airborne mixture of solid and liquid particles, such as dust, dirt and smoke. The PM most prevalent in urban environments includes PM10 (coarse particles including dust, mold and pollen) and PM2.5 (fine particles including gases from combustion and organic compounds). The major source of PM throughout the world today is the human combustion of fossil fuels from a variety of activities including traffic and road transport, industrial combustion, power generation, biomass (wood) and agricultural debris burning, and construction. Concentrations of PM in the air are affected by a number of human and weather factors, including how much soot the city produces, temperature, humidity, rain, and wind. PM2.5 and PM10 pose the greatest risks to human health, as they can penetrate deep into the lungs and enter the bloodstream. (17, 40, 6, 7, 26, 28, 42)

NO_2 NITROGEN DIOXIDE

Nitrogen dioxide (NO2) is the product of combustion processes; the principal sources include traffic, industry, shipping and households. NO2 makes up roughly 50 percent of ambient air pollution in urban areas, and concentrations are much higher in developing country metropolises. NO2 concentrations tend to be highest near densely crowded streets with heavy motor vehicle traffic, urban heat islands and power generation sites. NO2 levels tend to be highest in the morning and late afternoon, with peaks correlating with rush-hour traffic. NO2 exacerbates asthma and bronchitis symptoms, reduces lung function and increases the risk of heart attacks. (40)

SO_2 SULFUR DIOXIDE

In developing countries, sulfur dioxide (SO2) has the greatest prevalence among other key air pollutants and poses the greatest threat to large urban areas. A colorless and odorous gas, SO2 comes from both natural and human sources and is produced primarily from the combustion of coal and oil, especially in power plants and diesel

engines, and the smelting of mineral ores. In large cities, where coal is still widely used for domestic heating and cooling as well as for industrial and power formation, peak concentrations over as little as 10 minutes can reach 1,0002,000 µg/m3, which is more than double the WHO's Air Quality Guidelines. Exposure to SO2 increases the risk of hospitalization and death due to COPD, heart attack and asthma. (18, 23, 39)

O_3 GROUND-LEVEL OZONE

"Smog," or ground-level ozone, a colorless and highly irritating gas, is created when fossil fuel emissions from traffic, industrial facilities, power plants, electric utilities and refineries interact with sunlight and heat. High rates of urbanization directly impact ground-level ozone due to the increased presence of these fossil fuel-burning activities. These emissions are the major sources of nitrogen oxides and volatile organic compounds, the two precursors that contribute most to ozone formation, which react with sunlight to form ground-level ozone. Ozone increases the risk of hospitalization and aggravation of asthma and COPD. (7, 8, 11, 39, 19, 14)

Ozone travels with the prevailing wind and tends to reach higher concentrations in city suburbs, downwind locations and/or higher altitudes. This is particularly important in large urban areas in developing countries, as people living on the outskirts can be exposed to harmful levels of pollutants. (14, 40)

IMPACTS OF HEAT

The interactions between air pollutants and the state of the atmosphere, in part, determine the development, distribution and concentration of pollutants. Increased temperatures and extreme heat events will, on the whole, accelerate the development of harmful air pollutants, consequently increasing the impact of each of these pollutants on human health.

» Particulate Matter

Heat and sunlight accelerate the formation of PM in the atmosphere. Depending on the size and composition, PM can absorb the sun's energy/radiation, resulting in a net warming effect on the atmosphere. However, higher levels of humidity, particularly in coastal urban areas, can decrease PM levels. (8, 10, 12, 24, 29, 30, 35, 40, 44, 45)

» Nitrogen Dioxide

Most atmospheric NO2 is initially emitted as nitric oxide, which then reacts with ground-level ozone to produce NO2. Heat and sunlight increase ozone, and heat combined with humidity and increased water vapor can increase ozone in areas with already high levels of NO2 — urban heat islands, intersections with heavy motor vehicle traffic, industrial sites; consequently, the amount of atmospheric NO2 also rises. Similar to PM, NO2 also absorbs visible solar radiation, which can have a net warming effect in urban areas. (1, 24, 36)

» Sulfur Dioxide

While the direct relationship between heat and SO2 is still uncertain, increased temperatures have led to higher levels of SO2, while humidity and rainfall have reduced concentrations of SO2. As such, it can be broadly inferred that in tropical regions and climates driven by monsoons, higher temperatures may increase SO2 levels, but humidity and rainfall may have the opposite effect. (1, 24, 43)

» Ground-Level Ozone

As noted above, ozone is strongly correlated with increased temperature and tends to be greatest on warm, summer days. In the presence of both high concentrations of NO2 and bright sunshine, high ozone concentrations can form relatively rapidly, resulting in substantial pollution. (5, 13, 32, 37)

CONSEQUENCES FOR HEALTH

The health impacts of PM, NO2, SO2 and ground-level ozone are well-documented. In urban metropolises in developing countries, the combination of SO2 and PM form the majority of the health burden; their combined health impacts are greatest on those already suffering from preexisting conditions. Examples of the potential impacts of heat on health conditions either caused or exacerbated by high levels of each air pollutant include (6, 7, 11, 26, 38, 40, 42, 15):

» **Respiratory System**

- Increased hospitalization and mortality in COPD patients (PM, SO2, ozone, NO2)
- Exacerbation of asthma symptoms, especially in children (PM, NO2, SO2, ozone)
- Increased frequency and severity of bronchitis (PM, NO2)
- Lung inflammation (PM, SO2)
- Reduced lung function and growth (NO2)

» **Cardiovascular System**

- Increased hospitalization and mortality in heart disease patients due to increased incidence of arrhythmias and heart attacks (PM, NO2, SO2)
- Increased risk of heart attacks (PM, NO2, SO2)
- Increased hospitalization for heart failure (PM)

MOST VULNERABLE POPULATIONS AND LOCATIONS

CITY RESIDENTS MOST AT RISK

The overall risk of city residents is determined by age, people's activity, lifestyle, employment, housing conditions and socioeconomic status. The populations most vulnerable to the effects of air pollution and heat are (11, 40, 41, 43, 9, 28, 20, 33, 7, 3, 4, 35):

» **Infants and children** who lack a fully developed respiratory system, are active and spend more time outdoors, increasing exposure to heat and harmful pollutants.

» **Elderly people** are at risk due to their ailing conditions and high prevalence of underlying cardiovascular and/or respiratory diseases.

- **Urban residents with preexisting chronic cardiovascular and/or respiratory conditions** whose symptoms are easily exacerbated by high levels of combined heat and air pollutants.
- **Informal settlement and slum residents** who live in housing with inefficient cooling and cooking systems and have limited access to good housing in safe neighborhoods, nutritious food, decent jobs, health care services and other urban amenities (e.g., green spaces, cooling centers).
- **Outdoor laborers** (e.g., roadside vendors, construction workers and taxi drivers) working in dense areas of the city where pollutant emissions and concentrations are high.
- **Industrial, power generation and waste incineration facility workers**

Heat and Air Quality **VULNERABLE GROUPS**	
Populations	Infants and children
	Elderly
	People with preexisting chronic conditions
	Poor and marginalized people
Geographies	Asia
	Africa
	Latin America
	Tropical, urban megacities

GEOGRAPHICAL AREAS MOST AT RISK

Air pollution levels are normally higher in developing countries than in highly developed industrialized countries. As such, the global geographic risk includes large metropolitan areas in South and Southeast Asia, low-income countries in the eastern Mediterranean, western Africa, and parts of Latin America (Beijing, Dakar, Ho Chi Minh City, Jakarta, Karachi, Mexico City, Mumbai, Onitsha, etc.). These are the regions that already have consistently high levels of ambient air pollution, large urban and aging populations, and are projected to experience the greatest increases in days with temperatures above the lethal threshold of 35°C. The largest concentration of the classical indicators of ambient air pollution levels (PM10 and SO2) are found in Asia and Latin America, while the highest levels of ozone and NO2 are found in urban areas in Latin America and developed countries. The risk for Africa may be much higher, however, as only seven of 54 African countries have established air pollution monitoring systems. A UNICEF analysis of Africa found that air pollution resulted in the most premature deaths in 2013 and that outdoor air pollution levels rose by 60 percent between 1990 and 2017. These results indicate that rapidly growing populations and urbanization rates may increase the risk of deadly air pollution levels. (21, 31, 34, 40, 44)

STEPS TO REDUCE RISK

Municipalities can integrate health into urban planning, investments and policy decisions to reduce the combined risks of extreme heat and air pollution to human health. Reducing air pollution levels improves the health of all urban residents, but the poor and marginalized residents will reap the greatest benefits (17, 18, 21, 22, 25, 25, 41, 40):

- **Urban Greening Measures and Designs**
  - Developing green spaces, green "walls" in urban canyons and planting trees throughout the city and in dense corridors can promote cooling and biological air filtration.

- Constructing and retrofitting buildings with specific geometries and materials can promote the flow and dispersion of pollutants.

» **Governance for Reduced Emissions**

- Developing and enforcing building codes that require increased insulation, greater energy efficiency and good ventilation will reduce emissions and protect the health of growing urban populations.
- Carrying out systematic maintenance and inspection programs.
- Promoting the increased use of low-emissions fuels and renewable, combustion-free power sources (solar, wind, hydropower).

» **Efficient and Healthy Transportation Systems**

- Setting up efficient and cost-effective public transportation system to reduce motor vehicle use.
- Establishing walking and cycling networks.
- Transitioning to alternate fuels by, for example, enforcing the use of cleaner, heavy-duty diesel vehicles to reduce emissions.

» **Reduced Pollution from Industrial and Power Generation Facilities**

- Employing clean technologies that reduce industrial smokestack emissions.
- Reducing use of biogas and promoting clean fuels and devices for cooking.

» **Strengthened Health Systems**

- Upgrading the physical infrastructure of hospitals and clinics.
- Training doctors, nurses and community health workers on the effects of heat and pollution on health.
- Establishing or improving air quality monitoring systems and conducting public health analyses to better understand the specific, city-level impacts of pollution on human health and the city's most vulnerable areas.

Key Resources

- WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide
- WHO Global Ambient Air Quality Database
- United States Environmental Protection Agency (EPA) Air Quality Management Process
- EPA Criteria Air Pollutants
- Centers for Disease Control and Prevention (CDC) Air Quality Resources for Professionals

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