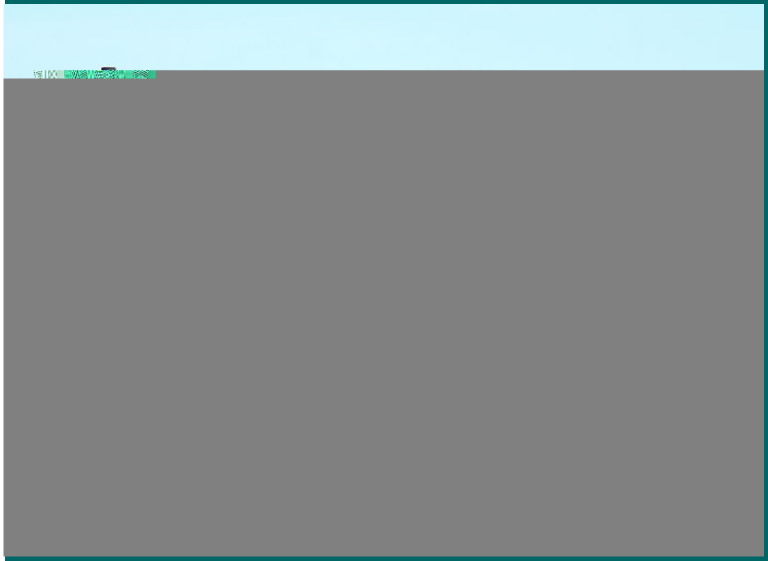
Emissions of Hazardous Air Pollutants from Coal-fired Power Plants



EMISSIONS OF HAZARDOUS AIR POLLUTANTS FROM COAL-FIRED POWER PLANTS

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About the Report

Scientists from Environmental Health and Engineering, Inc. (EH&E) were commissioned by the American Lung Association to prepare a report on public health and environmental impacts of hazardous air pollutant emissions from coal-fired power plants that would be a useful resource for the general public. This report represents the integrated effort of numerous talented individuals within our organization whose contributions were made under the direction of David L. MacIntosh, Sc.D., C.I.H., and John D. Spengler, Ph.D.

David L. MacIntosh, Sc.D. C.I.H., is a Principal Scientist and Associate Director of Advanced Analytics and Building Science at EH&E where he manages a group of scientists and engineers who specialize in determining the complex relationships among sources, pathways, and receptors of environmental stressors that influence public health in the built environment. Dr. MacIntosh is a former tenured faculty member of the University of Georgia and is currently an Adjunct Associate Professor at the Harvard School of Public Health where he teaches courses on exposure assessment and environmental management. He earned a doctorate in Environmental Health from the Harvard School of Public Health. He is also a Certified Industrial Hygienist. Dr. MacIntosh is active in professional service through the International Society for Exposure Science, the U.S. Environmental Protection Agency FIFRA Science Advisory Panel, the Centers for Disease Control and Prevention, and the World Health Organization.

John D. Spengler, Ph.D. is the Akira Yamaguchi Professor of Human Health and Habitation, Harvard School of Public Health and Director of the Sustainability and Environmental Management program at the Extension School. Dr. Spengler has conducted research in the areas of personal monitoring, air pollution health effects, indoor air pollution, and a variety of environmental sustainability issues. He is the author of numerous articles on air quality and other environmental issues, and co-author or co-editor of *Health Effects of Fossil Fuel Burning: Assessment and Mitigation*; *Indoor Air Pollution: A Health Perspective*; *Particles in Our Air: Concentrations and Health Effects*; and *Indoor Air Quality Handbook*. In 2003, Dr. Spengler received a Heinz Award for the Environment; in 2007, he received the Air and Waste Management Association Lyman Ripperton Environmental Educator Award; and in 2008 he was honored with the Max von Pettenkofer award for distinguished contributions in indoor air science from the International Society of Indoor Air Quality and Climate's Academy of Fellows.

EH&E is grateful to James E. Staudt, Ph.D., Andover Technology Partners, for preparing the first draft of sections on air pollution control systems for hazardous and criteria air pollutant emissions.

EH&E is also grateful to John Bachmann, Vision Air Consulting, LLC for providing input and advice on the science and policy matters presented in the report.

List of Figures:

LIST OF ABBREVIATIONS AND ACRONYMS

ACI	Activated carbon injection
ACS	American Cancer Society
ATSDR	Agency for Toxic Substances and Disease Registry
BTU	British Thermal Unit
CAA	Clean Air Act
CASAC	U.S. EPA Clean Air Scientific Advisory Committee

Toxicity and Impacts on Public Health and the Environment

- Hazardous air pollutants emitted to the atmosphere by coal-fired power plants can cause a wide range of adverse health effects including damage to eyes, skin, and breathing passages; negative effects on the kidneys, lungs, and nervous system; the potential to cause cancer; impairment of neurological function and ability to learn; and pulmonary and cardiovascular disease (USEPA, 1998; USEPA, 2011a; USEPA, 2011b).

- Public health risks associated with exposure to mercury in food and metals in airborne fine particulate matter are among the most notable adverse health and environmental impacts associated with emissions of hazardous air pollutants from coal-fired power plants.

- Coal-fired power plants can be significant contributors to deposition of mercury on soil and water.
  - A study in eastern Ohio reported that coal combustion accounted for 70% of the mercury present in rainfall (Keeler et al., 2006).
  - In the same area, 42% of the mercury in samples of rain collected in the summer was attributed to emissions from a coal-fired power plant located less than a mile away (White et al., 2009).
  - Mercury that deposits to the earth's surface from air can make its way into waterways where it is converted by microorganisms into methylmercury, a highly toxic form of mercury (Grandjean 2010).

- EPA has determined that exposure to fine particulate matter is a cause of cardiovascular effects including heart attacks and the associated mortality; is likely a cause of hospital admissions for breathing problems and worsening of existing respiratory illness such as asthma; and is linked to other adverse respiratory, reproductive, developmental, and cancer outcomes (USEPA, 2009a; CASAC 2010).

- Hazardous air pollutants, such as arsenic, beryllium, cadmium, chromium, lead, manganese, nickel, radium, selenium, and other metals, are integral components of fine particulate matter emitted directly from coal-fired power plants.

- The metal content of fine particulate matter has been linked to cardiovascular public health impacts in epidemiological and other studies (e.g. Zanobetti et al., 2009).

- In a recent population-based health impact assessment, particulate matter emitted directly from coal-fired power plants was estimated to account for an average of $3.7 billion[1] of public health damages each year (NRC, 2010).

- Environmental impacts of power plant hazardous air pollutant emissions include acidification of the environment, bioaccumulation of toxic metals, contamination of rivers, lakes, and oceans, reduced visibility due to haze, and degradation of buildings and culturally important monuments.

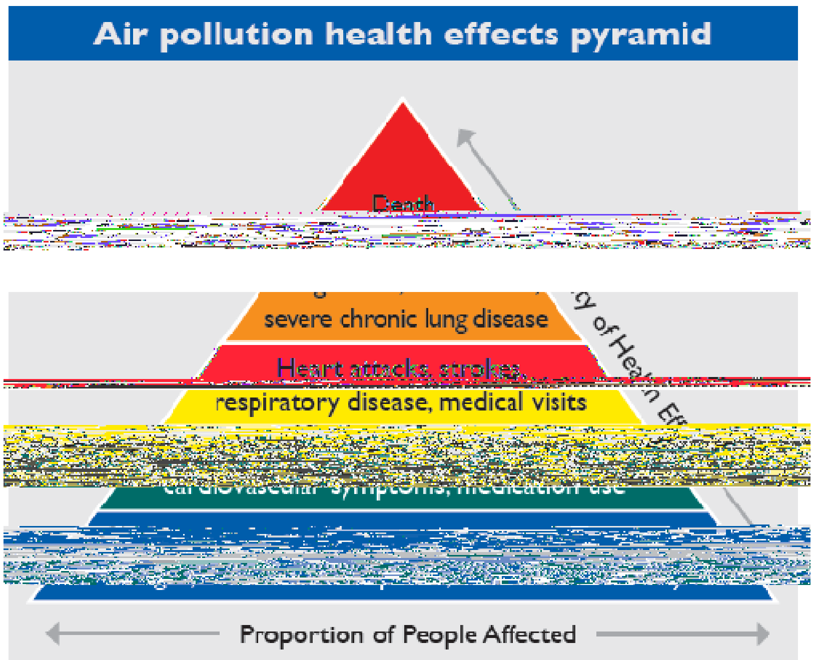

Figure 1. Air Pollution Health Effects Pyramid. Health effects of air pollution are portrayed as a pyramid, with the mildest and most common effects at the bottom of the pyramid, and the more severe but less frequent effects at the top of the pyramid. The pyramid shows that as severity decreases the number of people affected increases. Exposure to air pollution can affect both the respiratory and the cardiac systems. Adapted from USEPA, 2010b.

Transport and Range of Impacts

- Hazardous air pollutants released from coal-fired power plants influence environmental quality and health on local, regional, and global scales.

[1] Based on average damages of $9 million per coal-fired power plant determined in an analysis of 406 plants.

- Impacts of certain hazardous air pollutants, including most acid gases and some forms of mercury, appear to impact most heavily on the immediate vicinity of the facility.

- Impacts of non-mercury metals and other persistent hazardous air pollutants released from coal-fired power plants are greatest near the source, but can also influence the environment and health far from the source.
  - Analyses of coal-fired power plants have found that public health damages per person were two to five times greater for communities near the facilities than those for populations living at a greater distance from the plants (Levy and Spengler 2002).
  - Analyses conducted by EPA, the National Research Council, and other scientists show that emissions from coal-fired power plants cross state lines and impart public health damages on a regional scale.

Emission Controls for Hazardous Air Pollutants

- Emission rates of hazardous air pollutants vary widely among coal-fired power plants in the United States, in part because of variation in the use of technologies that can remove pollutants from exhaust gases.

- Hazardous air pollutant emissions from a sample of coal-fired power plants that use multiple modern control technologies were 2 to 5 times lower on average than for a random sample of plants selected by EPA.

- Controls on acid gas and non-mercury metal emissions are likely to reduce emissions of sulfur dioxide and primary particulate matter. As a result, controlling hazardous air pollutant emissions is expected to generate substantial public health and environmental benefits.

- Use of more effective control technologies by more coal-fired power plants as a result of the Utility Air Toxics Rule is expected to reduce the public health and environmental impacts of electricity generated by combustion of coal.

Table 1. Toxicological and Environmental Properties of Hazardous Air Pollutants (HAPs) Emitted from Electric Generating Stations Fueled by Coal.			
Class of HAP	**Notable HAPs**	**Human Health Hazards**	**Environmental Hazards**
Acid Gases	Hydrogen chloride, Hydrogen fluoride	Irritation to skin, eye, nose, throat, breathing passages.	Acid precipitation, damage to crops and forests.
Dioxins and Furans	2,3,7,8-tetrachlorodioxin (TCDD)	Probable carcinogen: soft-tissue sarcomas, lymphomas, and stomach carcinomas. May cause reproductive and developmental problems, damage to the immune system, and interference with hormones.	Deposits into rivers, lakes and oceans and is taken up by fish and wildlife. Accumulates in the food chain.
Mercury	Methylmercury	Damage to brain, nervous system, kidneys and liver. Causes neurological and developmental birth defects.	Taken up by fish and wildlife. Accumulates in the food chain.
Non-Mercury Metals and Metalloids (excluding radioisotopes)	Arsenic, beryllium, cadmium, chromium nickel, selenium,		

1.0 INTRODUCTION

In accordance with the Clean Air Act, the U.S. Environmental Protection Agency (EPA) will propose new limits on emissions of hazardous air pollutants released to the atmosphere from large power plants that burn coal and oil to generate electricity for sale. EPA will issue the proposed rule by March 16, 2011 as required by a court settlement (US District Court Consent Decree, 2010). The proposal will establish, for the first time, federal limits on emissions of hazardous air pollutants from coal- and oil-fired power plants. Commonly abbreviated as HAPs, hazardous air pollutants are chemical pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive problems or birth defects, and that adversely affect the environment. At this time, EPA has identified 187 chemical pollutants as HAPs (USEPA, 2010c).

Known formally as the National Emission Standards for Hazardous Air Pollutants for Utility Boilers, this rule will apply to all coal- and oil-fired combustion units that generate more than 25 megawatts of electricity. The new limits are to be based on the emissions performance of the maximum available control technology (MACT). According to the Clean Air Act, the MACT standards for existing sources are to be at least as stringent as the average emissions achieved by the best performing 12 percent of existing sources. For new sources, MACT standards are to be at least as stringent as the control level achieved by the best controlled similar source. The set of regulations and impending limits for electric generating stations is known as the "Utility Air Toxics Rule". Unlike most industry sectors, coal-fired power plants are currently not subject to federal limits on mercury and other HAP emissions.

The American Lung Association commissioned Environmental Health & Engineering, Inc. to prepare this report on HAPs and power plants that generate electricity by burning coal. The report is intended to be a resource for the non-scientific community that summarizes:

- Releases of HAPs to the atmosphere from combustion of coal (i.e., emissions),
- How these substances are transported and where they end up in the environment (i.e., transport and fate),
- Hazards posed by these HAPS and their impacts on human health and the environment (i.e., toxicity and impact), and
- Controls on releases of HAPs and the likely implications of more widespread use on coal-fired power plants (i.e., air pollution control technologies and their benefits).

2.0 HAZARDOUS SUBSTANCES IN COAL

Coal is a carbon-rich mineral that has been used to generate electricity in this country since the 1800s (NRC 2010). The United States is home to more than a quarter of the world's recoverable coal reserves. In 2008, more than 1 billion tons (2 trillion pounds) of coal was extracted from the earth at more than 1,600 mining operations throughout the country, approximately half of which was used for electricity generation. The electric energy generated from coal accounts for 45% of all electricity produced in the United States (USDOE, 2009a).

Coal is formed from fossilized plant life that is subjected to pressure and heat over millions of years. As coal is formed, it incorporates substances (impurities) from the surrounding soil and sediment, including sulfur and heavy metals. Some of these impurities consist of hazardous materials such as mercury, arsenic, lead, and nickel. The nature and extent of impurities in any given seam of coal depends on the conditions over the long period during which the coal is formed.

Ultimately however, coal is classified into one of four types based on its heating value, ash content, and moisture, which in part reflect the extent of impurities present. As shown in Table 2, two types of coal – bituminous and sub-bituminous – account for over 90% of coal use in the country. Pyrite, a mineral rich in iron and sulfur, is a common impurity in bituminous coal, and is a primary host for arsenic and mercury. Sub-bituminous coal contains substantially less sulfur than bituminous coal and is therefore often favored by power plants that desire relatively low emission rates of sulfur dioxide, an important precursor to acid rain and fine particle pollution. Coal is sometimes washed with water and special chemicals to reduce some of the impurities. When burned, the impurities in coal are released and can be emitted to the atmosphere if not captured byoften f0e()]TJ-1s,2J15.240s4(edost2 Twypeoyd)1t c40.1857t0.0007

Coal-fired power plants emit 84 of the 187 HAPs identified by EPA as posing a threat to human health and the environment (USEPA, 2007). With total emissions of 386,000 tons of HAPs annually, coal-fired power plants account for 40% of all HAP releases from point sources[2] to the atmosphere, more than any other point source category (Figure 4). These emissions include both 'fuel-based pollutants' – e.g., metals,[3] hydrogen chloride, hydrogen fluoride, and mercury – that are a direct result of contaminants in the coal that is combusted; as well as 'combustion-based pollutants' – e.g., dioxins and formaldehyde – which are formed during burning of the coal (USEPA, 2011a).

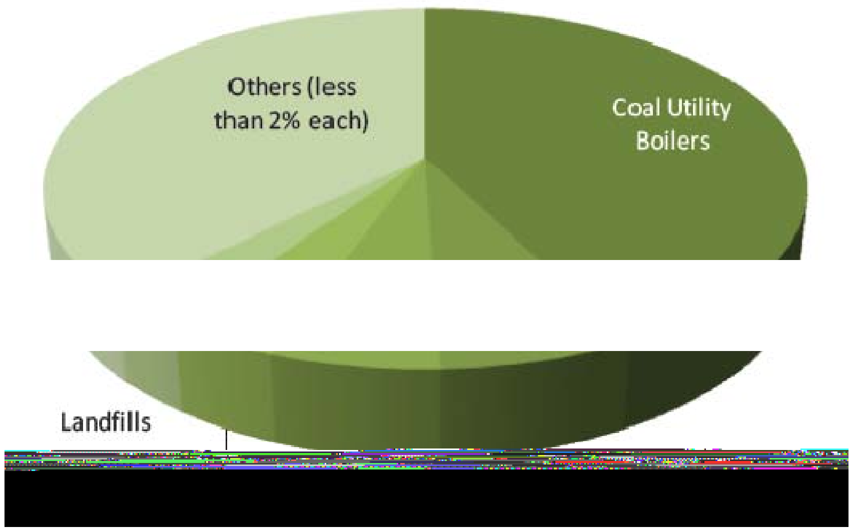

Figure 4 Proportion of Total Hazardous Air Pollutant Emissions From Coal-Fired Power Plants and Other Stationary Sources According to Data in the National Emissions Inventory from the U.S. Environmental Protection Agency (USEPA, 2007).

HAPs emitted from coal-fired power plants include neurotoxins such as mercury and lead, corrosive substances such as hydrochloric acid, carcinogens such as arsenic and benzene, radioactive elements such as radium, and potent organic carbon-based toxins such as dioxins and formaldehyde (USEPA, 2007; USEPA, 2010a). In addition to being the single largest class of total point source HAP emissions, coal-fired power plants are also a major source of emissions for many of these individual HAPs. As shown in Table 3, combustion of coal to generate electricity is the predominant source of hydrochloric acid emissions to the atmosphere (as well as sulfur dioxide and oxides of nitrogen, which are the most

[2] The term 'point source' refers to emissions released from a source that is stationary (does not move). Point sources are distinct from sources that can cover a large area, such as a wildfire, and mobile sources such as cars, trucks, and off-road machinery including bulldozers and other earth-moving equipment. Values reported here are based on the latest EPA National Emissions Inventory. EPA is anticipated to publish updated estimates of hazardous air pollutants from coal-fired power plants as part of the Utility Air Toxic Rule.

[3] As in some EPA materials, the class of pollutants referred to for simplicity here as 'metals' includes some elements (e.g. arsenic and selenium) that are not, strictly speaking, fully metallic.

important sources of atmospheric acidity). Likewise, electricity generating stations powered by coal account for 46% of mercury, and 60% of arsenic released to the atmosphere from point sources.

Table 3. Contributions of Coal-Fired Power Plants to Selected Hazardous Air Pollutant Emissions

Hazardous Air Pollutant	Percentage of Point Source Emissions
Acid Gases (hydrochloric acid and hydrofluoric acid)	76%
Arsenic	60%
Beryllium	28%
Cadmium	30%
Chromium	20%
Cobalt	34%
Lead	15%
Manganese	11%
Mercury	46%
All Non-Mercury Metal HAPs Emitted by Coal-Fired Power Plants	[redacted]

Table 4. Toxicological and Environmental Properties of Hazardous Air Pollutants (HAPs) Emitted from Electric Generating Stations Fueled by Coal.			
Class of HAP	**Notable HAPs**	**Human Health Hazards**	**Environmental Hazards**
Acid Gases	Hydrogen chloride, Hydrogen fluoride	Irritation to skin, eye, nose, throat, breathing passages.	Acid precipitation, damage to crops and forests.
Dioxins and Furans	2,3,7,8-tetrachlorodioxin (TCDD)	Probable carcinogen: soft-tissue sarcomas, lymphomas, and stomach carcinomas. May cause reproductive and developmental problems, damage to the immune system, and interference with hormones.	Deposits into rivers,

3.3 Health and Environmental Impacts

Acid Gases

Hydrogen chloride and hydrogen fluoride are strongly corrosive acids, and coal-burning power plants are reported to be the largest anthropogenic source of hydrogen chloride and hydrogen fluoride emissions to air (USEPA, 2007). The amounts of hydrogen chloride and hydrogen fluoride produced by a particular power plant depend in large part on the concentrations of chloride and fluoride in the coal that is burned, and whether any emission control systems are in use.

Hydrogen fluoride is emitted as a gas or particle and can be adsorbed onto other particles (USEPA, 1998). Hydrogen fluoride particles tend to remain suspended in the atmosphere and can travel 500 study found also acid gases and particle pollution were associated with reduced lung function (Gauderman et al., 2004). The focus of these landmark studies on children is significant; as children are likely more vulnerable than healthy adults to air pollution, including acidic gases and particles. Children have narrower airways, a faster breathing rate and tend to spend more time outdoors than adults, resulting in greater overall exposures (Bateson and Schwartz, 2008).

Chloride released from hydrogen chloride is associated with cloud acidity (USEPA, 1998) which can contribute to acid deposition over a regional scale. While much of the strong acidity has generally been thought to be related to sulfur dioxide and nitrogen oxide emissions, hydrogen chloride in particular likely plays a significant role in acid deposition in the vicinity of coal-burning power plants (USEPA, 1998).

Dioxins

The term dioxins refer to the family of structurally and chemically related polychlorinated dibenzo dioxins and polychlorinated dibenzo furans; another group of HAPs released to the atmosphere by coal-fired power plants. Dioxins are mainly formed as a by-product of combusting fossil fuels (WHO, 2010). Dioxins and furans are similar in chemical structure and consist of two six-sided rings composed of carbon and oxygen to which are attached either hydrogen or chlorine atoms. The number and position of chlorine atoms on these molecules determines the identity of each specific type of dioxin and furan, and also strongly influences their toxicity.

Dioxins have been measured in the atmosphere in both gas and particle forms. The low-chlorinated compounds have been found to be most prevalent in the gaseous form and the highly-chlorinated compounds dominant in particle form (Oh et al., 2001). The compounds undergo photochemical reactions in the lower levels of the atmosphere (troposphere). The lower-chlorinated compounds are removed from the atmosphere primarily by this photochemical process in as little as one day. The higher-chlorinated compounds are often associated with small particles and may reside in the atmosphere for more than 10 days (Atkinson, 1991) during which time people can be exposed through inhalation.

Most of the higher chlorinated dioxins eventually deposit onto soil or water bodies. Deposition of airborne particle-bound dioxins is likely the most important direct source of dioxin input to water and soil ecosystems (Lohmann and Jones, 1998; Zhang et al., 2009), where they tend to accumulate in sediments and persist in the environment for many years. Dioxins have a high affinity for fatty molecules, which allows them to accumulate in aquatic and terrestrial food webs. As a result, humans can be exposed to these compounds by consumption of fish and meat. A study conducted by the Food Safety and Inspection Service of the U.S. Department of Agriculture in 2002-2003 found dioxin-like compounds in four classes of U.S. meat and poultr

Mercury

EPA identifies mercury as one of the most toxic HAPs released by coal-fired power plants, primarily

Panel A: Location and Size of US Power Plants by Mercury Emissions

Emissions of these metals

The fact that non-mercury metals emitted from exhaust stacks of coal-fired power plants comprise part of PM is important. When inhaled by people, some particles deposit along the respiratory tract, while others penetrate deeply into the lung where they can enter the bloodstream. These particles aggravate the severity of chronic lung diseases causing loss of airway function, cause inflammation of lung tissue which results in the release of chemicals that impact heart function, and leads to changes in blood chemistry that results in clots that can cause heart attacks (USEPA, 2010b). Inhalation of $PM_{2.5}$ over both short and long periods of time is recognized to cause cardiovascular effects, including heart attacks and the associated mortality. Exposure to $PM_{2.5}$ is also a likely cause of hospital admissions for breathing problems and worsening of existing respiratory illness such as asthma. $PM_{2.5}$ exposure has been linked to other adverse respiratory, reproductive and developmental, and carcinogenic outcomes as well (USEPA 2009a; CASAC, 2010).

Some of the largest studies of health effects related to fine particles were conducted with participation from healthy adults living in areas across the United States. In one of the first and most important of these community-based studies, a research group from the Harvard School of Public Health followed over 8,000 healthy adults living in six U.S. cities for more than 14 years (the Six Cities Study). They concluded that death rates were higher in cities with higher fine particle pollution levels; in other words, people in those cities didn't live as long as people in cities with cleaner air (Dockery et al., 1993). The association between fine particles and early death was repeated in two much larger studies using an American Cancer Society (ACS) database of over 500,000 adults located in 151 cities across the country (Pope et al. 1995; Pope, et al. 2002). In 2000,ty361 0( )]TJ-22.03m( )5.432 T(icles beties0he lam;3vex4tudie irritation of the eyes, nose, and throat, chronic bronchitis, restriction of activities, and temporary changes in lung function.

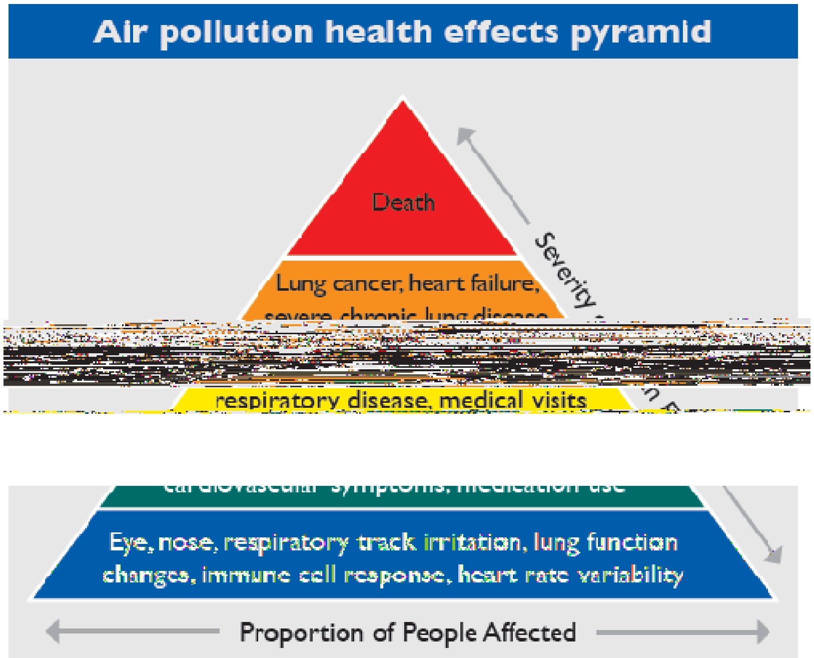

Figure 8. Air Pollution Health Effects Pyramid.

Health effects of air pollution are portrayed as a pyramid, with the mildest and most common effects at the bottom of the pyramid, and the more severe but less frequent effects at the top of the pyramid. The pyramid shows that as severity decreases the number of people affected increases. Exposure to air pollution can affect both the respiratory and the cardiac systems. Adapted from USEPA, 2010b.

The presence of metals or other pollutants in or on particles may be important in determining the toxicity of fine particles (Bell et al., 2007). Researchers have found that metals interact with particles to generate 'reactive oxygen species' which limit the body's ability to repair damage to its cells and contribute to inflammation of tissue (Carter et al., 1997; Gurgueita et al., 2002; Wilson et al., 2002; Valko, 2008). Exposure to particles enriched in sulfate, selenium, iron, nitrate, and organic carbon have been associated with immune cell response and heart variability in human volunteers (Huang et al., 2003; Chuang et al., 2007). A recent community-based study that used Medicare records from 26 communities found greater effects on hospital admissions for cardiovascular disease when the levels of certain metals, including chromium and nickel, were elevated in the $PM_{2.5}$ (Zanobetti et al., 2009). Similarly heart attack admissions were elevated for $PM_{2.5}$ enriched in arsenic, chromium, manganese, nickel and organic carbon. In the same study, diabetes-related hospital admissions were associated with

PM high in arsenic, organic carbon and sulfate,

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Figure 9

Table 5. Residence Time of Hazardous Air Pollutants in the Atmosphere			
HAP Group	**Indicator Pollutant(s)**	**Residence Time***	**Likely Range of Transport**
Mercury	Methylmercury	7–10 days	Local, regional, global
Metals	Arsenic	7-9 days (lifetime)	Local, regional, global
	Beryllium	10 days (lifetime)	Local, regional, global
	Cadmium	1-10 days (lifetime)	Local, regional, global
	Chromium	Up to 7-10 days	Local, regional, global
	Nickel	Up to 30 days (half-life)	Local, regional, global
	Manganese	Several days (half-life)	Local, regional
	Selenium	1-10 days	Local, regional, global
	Lead	Up to 10 days	Local, some regional
Radioisotopes	Uranium, Radium	Not reported	Local, regional, global**
Dioxins/Furans	Chlorinated dibenzo-p-dioxins	0.5 - 9.6 days (lifetime)	Local, regional, global
	Dibenzofurans	4 days (half-life)	Local, regional
	Chlorodibenzofuran (CDFs)	More than 10 days (half-life)	Local, regional, global
Aldehydes	Formaldehyde	<20 hours (half-life)	Local
Volatile Organic Compounds	Benzene	4–6 hour (half-life in presence of NOx and SO_2)	Local
	Xylene	8–14 hours (half-life)	Local
	Toluene	13 hours (half-life)	Local

observations are consistent with the measurements of local mercury deposition that were described in Section 3.3.

Local impacts of coal-fired power plant HAP emissions are not limited to HAPs with short atmospheric residence times, however. Longer-lived HAPs are also present in the immediate vicinity of the source before being transported to other areas. These include metals such as lead, arsenic, cadmium and chromium. Potential exposures to these HAPS can therefore be elevated in areas surrounding a coal-fired power plant. For instance, a study of coal-fired power plants in New England found that public health damages per person are two to five times greater for communities near the facilities than for populations living at a greater distance from the plants (Levy and Spengler, 2002).

In addition to properties of a given pollutant and weather, the location and magnitude of local impacts from emissions of coal-fired power plant HAP are influenced by the height of the emission point above ground level. In general, lower stacks result in higher impacts near the source than taller stacks. The relationship between stack height and location of ground-level impacts is illustrated in Figure 10.

Figure 10 Schematic of location of initial ground-level impacts in relation to height of hazardous air pollutant release.

Stack heights for coal-fired power plants in the U.S. are 440 (134 meters) feet on average and range from 15 feet (about 4 meters) to 1,040 feet (about 316 meters) above ground level (USEPA 2010a). Corresponding maximum ground-level impacts range from 500 feet (about one-tenth of a mile) to 4,000 feet (about three-quarters of a mile). Consequently, the greatest ground-level impacts of HAPs emissions from any given coal-fired power plant are typically within a mile of the facility.

Tall exhaust stacks can mitigate local air quality impacts in general, although higher discharge points also release pollutants at an altitude where they are more readily transported on a regional and even global scale. Taller stack heights therefore enhance instate transport of HAPs and other pollutants. Markers of primary and secondary coal combustion have been reported in many analyses of the composition of regional fine particulate matter pollution (e.g.; Lee et al., 2002; Lee et al., 2003; Lee et al., 2006; Rutter et al., 2009). Regional transport of coal-fired power plant emissions translates to regional impacts on public health as well. One analysis of emissions from a coal-fired power plant in Wisconsin found that 80% of total public health impacts occurred beyo

Another example of regional impacts of coal-fired power plant emissions is provided in Figure 11. In this case, emissions of primary PM, sulfur dioxide, and oxides of nitrogen were modeled for 11 coal-fired power plants in Michigan and used to predict annual average concentrations of $PM_{2.5}$ for counties across the continental United States. As shown on the map, the highest $PM_{2.5}$ impacts from the plants were predicted to occur throughout the Great Lakes region and parts of New York and New England.

Figure 11 Annual Average Concentrations of Fine Particulate Matter ($PM_{2.5}$) Estimated for Counties of the Contiguous United States as a Result of Emissions of Primary $PM_{2.5}$, Sulfur Dioxide, and Oxides of Nitrogen from 11 Coal-Fired Power Plants in Michigan (EH&E, 2011).

Three major categories of air pollution control equipment are used to reduce emissions of HAPs including systems for acid gases, particulate matter, and mercury (Table 6). A portion of coal-fired power plants in the U.S. already use these technologies. More facilities are expected to install these or similar technologies in response to the new Utility Air Toxics Rule.

Table 6. Currently Available Control Technologies in Use for Reduction of Emissions of Air Toxics from Coal-Fired Power Plants

Control Technology	Which Pollutants Are Controlled?	How Does this Technology Work?	Number of Coal-Fired-Power Plants Using This Technology
Acid Gas Control Technologies			
Wet Flue Gas Desulfurization (FGD) (Scrubbers)	HAPs: Hydrogen chloride Hydrogen fluoride Hydrogen cyanide Mercury Collateral Pollutants Sulfur dioxide Particulate matter	Liquid mixed with limestone is sprayed into the emission, producing wet solid by-pr(10.87W Tw[(Hydrogo(7no203 Tw[(in	

Because of the cost of wet scrubbers (and to a le

The public health benefits of additional PM and sulfur dioxide controls could be substantial. The potential value of collateral benefits from the Utility Air Toxics Rule is indicated EPA's recent Regulatory Impact Analysis for MACT on industrial boilers (USEPA 2011a). In that analysis, EPA estimated that public health benefits of at least $22 billion to $54 billion would be achieved by MACT

6.0 CONCLUSIONS

The U.S. Environmental Protection Agency (EPA) will propose new limits on emissions of selected hazardous substances to the atmosphere from utilities that burn coal and other fossil fuels. The proposal will set new limits on emissions of hazardous air pollutants, 187 chemicals identified by EPA according to criteria established by Congress. This is the first time that emissions limits for HAPs will be required on all medium and large-scale power pl

- Hazardous air pollutant emissions from a sample of coal-fired power plants selected because of their use of multiple control technologies were 2

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