Iowa Coal & Health

A Preliminary Mapping Study

photo by Paul Deaton

A Report by the Iowa Chapter of Physicians for Social Responsibility

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ABOUT PHYSICIANS FOR SOCIAL RESPONSIBILITY

PSR has a long and respected history of physician-led activism to protect the public's health. Founded in 1961 by a group of physicians concerned about the impact of nuclear proliferation, PSR shared the 1985 Nobel Peace Prize with International Physicians for the Prevention of Nuclear War for building public pressure to end the nuclear arms race. Today, PSR's members, staff, and state and local chapters form a nationwide network of key contacts and trained medical spokespeople who effectively target significant threats to global survival. Since 1991, when PSR formally expanded its work by creating its environment and health program, PSR has addressed the issues of global warming and the toxic degradation of our environment. PSR presses for policies to curb global warming, ensure clean air, generate a sustainable energy future, prevent human exposures to toxic substances, and minimize toxic pollution of air, food, and drinking water. **Iowa PSR** is a proud member of this esteemed family of physician and health professional activists.

Cover photo: Grain processing plant in Muscatine, Iowa located within 1500 feet of an elementary school. Taken February 20, 2010

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Executive Summary

This report represents a preliminary effort to correlate the known disease burden and costs to Iowans of relying on coal to produce energy. Information was drawn for correlation and analysis from a variety of publicly available scientific resources, databases, and recently published research pertinent to Iowa. Geographical mapping techniques were utilized to synthesize graphical views comparing the distributions of a group of index diseases with a variety of environmental pollution sources to facilitate visualization of these complex data sets. Qualitatively, results are provocative and strongly suggest correlations between coal combustion and health in Iowa. Areas of monitoring and reporting where inadequate information hampers the ability to make the highest quality estimates of health effects of coal combustion in Iowa are identified.

Ninety-two percent of Iowans live within 30 miles of a coal plant, and almost one out of three Iowa children attend school in close proximity to a coal plant. Additionally, Iowa is home to several of the oldest, least efficient and most polluting coal burning power plants in the nation, those grandfathered and exempted from stricter emissions limits after passage of the Clean Air Act in 1977. This means that not only does Iowa have more power plants per capita than almost all states, but many of Iowa's power plants emit relatively more pollution per unit of energy produced because of their age. Finally, Iowa also disposes a disproportionate amount of coal combustion waste. Numerous toxic substances naturally found in coal are concentrated in such waste. Iowa has lax regulations on coal combustion waste disposal and allows waste from other states to be brought into Iowa for disposal. Thus Iowa absorbs the waste from its own plants as well as that produced elsewhere despite the potential health and environmental impacts of the many toxic substances involved.

Most Iowans, including health care providers and public health workers, are not aware of the intensity of burning coal in Iowa or of coal combustion related health risks. To best serve patients, health care professionals have a responsibility to understand these issues and inform their patients about specific environmental health risks. While health care providers have a duty to prevent disease, they may be unaware of effective measures to reduce or prevent unperceived health risks. This report begins the education process in Iowa.

Burning Coal Health Costs

Coal combustion emissions and waste residue contain numerous pollutants hazardous to health. Substantial scientific evidence demonstrates health and environmental harms at every stage of coal's life cycle, from the coal mine to the coal ash. No matter when, where, or how coal is mined, cleaned, transported, stored, burned, or its waste products disposed, coal based energy produces costly immediate and long term impacts on human health and the environment. Pollutants released into the environment when burning coal include mercury, fine particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic chemicals (VOC), and a long list of other harmful substances, including importantly, carbon dioxide.

These coal related pollutants accumulate in the environment and in human bodies. Fine particulate matter in particular is known to penetrate deeply into lung tissue and pass into the general circulation and cause disease in other organ systems. Both long- and short-term exposures to ambient levels of particulate matter air pollution have been associated with premature mortality. Coal is one of the major sources for atmospheric fine particulate matter. At the national level coal is responsible for about 19% of particulate matter, but in Iowa it accounts for 25%.

Products of coal combustion are known to induce or exacerbate asthma, chronic obstructive pulmonary disease (COPD), cardiovascular, and neurologic diseases. Each of these conditions are increasing in the population as a whole and contribute significantly to four of the top five leading causes of death in the US: heart disease, cancer, stroke, and chronic lower respiratory diseases. In fact, burning coal contributes to or exacerbates many of the most significant public health problems faced today all around the world. Technologic improvements installed by coal industries lessen the amount of hazardous substances released, yet Iowans across the state, continue to be exposed regularly to coal based pollutants that exceed federal standards–standards that many agree could be much stronger.

Some Iowans are more vulnerable than others to air and water pollution. Children, elders, outdoor workers, and Iowa's minority populations are more susceptible to the harmful effects of burning coal. The burden in suffering, lost work and school days, and economic costs to Iowa, not just to those directly impacted, is significant. Nevertheless, coal is rarely mentioned as a potential causative factor in discussing these costly diseases with affected patients or in public health campaigns.

In many parts of the state coal is one of several sources of airborne irritants. Coal emissions readily interact with several other unregulated pollutants intensively distributed across Iowa. For example, products of coal combustion interact and combine with the chemicals released by large scale agriculture. Given Iowa's intense and variable wind patterns and the presence of coal burning across much of the state, rural Iowans are also adversely impacted. The copious use of nitrogen fertilizers on Iowa's vast corn fields, and the large number of confined animal feeding operations (CAFOs) both release reactive nitrogen, sulfur oxides and fine particulate matter which in a manner similar to coal adversely affects health, the environment, and the climate.

Most official attention and concern focuses on the high financial costs incurred by any regulation of coal, or the promotion of cleaner alternatives without serious attention to very real health costs. Utilizing the Environmental Protection Agency's Co-Benefits Risk Assessment (COBRA) Screening Model, it is estimated that reducing the level of emissions in Iowa to that found on average in most states would save the state $71,785,903 on health expenditures annually. Most of the savings are due to the reduction in premature mortality from reduced exposure to fine particulate matter. Reduction in chronic illnesses, chronic bronchitis and non-fatal heart attacks, account for a savings of $4,756,373 or 6.6% of the total. The rest of the savings on health outcomes in this scenario are found in reductions in infant mortality, respiratory and cardiovascular hospital admissions, acute bronchitis, upper and lower respiratory symptoms, asthma emergency room visits, minor restricted activity days and lost work days.

Geographical Informations Systems (GIS) mapping techniques provide a basis for visually demonstrating and examining the distribution of pollutant emissions and the specific health concerns of coal for Iowans: asthma, COPD, acute respiratory infections, ischemic heart disease, stroke, respiratory cancer, and diabetes. Iowa enjoys an image of being a clean and healthy rural state, but when the sites and emission characteristics of Iowa's coal burners are layered over the state's health a picture emerges of several "hot spots" for excess prevalence of these diseases of concern.

Available data indicates that the current level of effort to identify, track, monitor or regulate coal related risks are inadequate to protect public health. Only a small number of the components found in coal emissions are monitored or regulated despite their known or suspected adverse health impacts. The interacting nature of pollutants from several sources and the final common expression of diseases as manifestations of exposures makes assigning specific blame to one source or another difficult but not impossible.

As scientific awareness of potential harms induced by exposure to coal combustion continues to grow, public awareness and the ability to monitor or intervene in the production of coal related environmental toxic elements remains limited. The report suggests further paths of investigation and possible strategies for prevention and reduction of known health risks. Health professionals, as community leaders, are encouraged to take active roles in advocating for a healthier future for Iowans.

Recommendations

Of the detailed steps required to promote health and prevent health risks related to coal included at the end of the report, the authors feel the following items are most urgently needed to reduce dependence on coal, protect public health and the environment:

- Support funding to more comprehensively track and monitor adverse health events
- Tightened standards for energy efficiency and their enforcement
- A moratorium on new coal plants in Iowa & shuttering of the oldest burners
- Tightened standards for $PM_{2.5}$
- Systematized clean-up and containment of coal ash waste at the state & federal level
- Elimination of coal subsidies and tax and financial incentives

Undoubtedly, these recommendations will not be easy or quick. These and others will require efforts at all levels local, state, regional, national and international, to bring about the changes most urgently needed. Long term improvements and regulations at any level require public funding and oversight. Efforts have already begun in some areas in various Iowa farming communities or on Iowa's college campuses. The authors hope that readers will utilize this information to create a healthier Iowa by supporting such efforts and promoting cleaner, sustainable alternatives to unhealthy coal.

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Glossary of Terms, Abbreviations and Acronyms

Airshed: Geographical area that shares the same air mass due to topography, meteorology and climate

Ambient PM: Fine Particulate Matter found in the immediate surrounding area

ATSDR: Agency for Toxic Substances and Disease Registry

Biomass: total mass of living matter (plant material, vegetation, or agricultural waste) within a given unit of environmental area used as a fuel or energy source

CAFOs: Confined Animal Feeding Operations; relating to or also referred to as AFOs—Animal Feeding Operations

COPD: Chronic Obstructive Pulmonary Disease. Disorder that persistently obstructs bronchial airflow, generally permanent, progressively worse over time

CCW:Coal Combustion Waste, also referred to as Coal Combustion Residue

CERCLA: Comprehensive Environmental Response Compensation and Liability Act

COBRA: Co-Benefits Risk Assessment Screening Model used by EPA to estimate health effects and costs of air pollution

DNR: Division of Natural Resources

ED: Emergency Department

EIA: U.S. Energy Information Administration

GAO: Government Accounting Office

GIS: Geographic Information System: a system of hardware and software used for storage, retrieval, mapping, and analysis of geographic data

HAPs: Hazardous Air Pollutants

Health Literacy: The degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions

ICR: Information Collection Rule (an EPA term used on many of its reports)

KWH: Kilowatt hour. Magnitude of energy used at the household level

Love Canal Disaster: Refers to the town built on a toxic waste site that then experienced a large number of serious adverse health outcomes and is now synonymous with environmental mismanagement. Its history is why the federal government created the Environmental Protection Agency's Superfund in 1980 making responsible parties liable for the cleanup of environmental hazards

MWH: Megawatt hour or 1,000 KWH. Magnitude of energy used at the industrial level

NAAQS: National Air Quality Standards

Non-attainment: A locality where air pollution levels persistently exceed National Ambient Air Quality Standards for the criteria pollutants designated in the Clean Air Act established by the Environmental Protection Agency

NO_x: Nitrogen Oxides

RES: Renewable Electricity Standard

SO_X: Sulfur Oxides, often short hand for Sulfur Dioxide

Spatial Autocorrelation: The degree of relationship that exists between two or more spatial data variables; patterned variation among spatial phenomena. Spatial autocorrelation statistics measure and analyze the degree of dependency among observations in a geographic space

Superfund Site: a toxic site requiring cleanup which has been placed on the National Priorities List maintained by the United States Environmental Protection Agency (EPA)

VOCs: Volitile Organic Chemicals

Wind Rose: Graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location

Introduction

A Brief History of Concerns

"To millions of our town-dwellers smoke is just what comes out of the chimney, as coal is just what goes on the fire. The idea that smoke is a "problem," something to be prevented, simply does not exist."

— Arnold Marsh, 1947[13]

Health care providers first began to realize that burning coal harms human and environmental health during the pre- and early industrial revolution, in London, Chicago, Pittsburgh, and elsewhere. Unregulated burning of coal in British and other burgeoning urban areas meant the inhabitants could no longer produce adequate amounts of food because trees and plants were dying due to the corrosive effects of the accumulated soot. It was also apparent that their populations experienced increased morbidity and mortality because of the pervasive coal based smog and other direct exposures.[2]

Despite the experience in the world's largest cities, most people remained unconcerned. Burning coal was once an obvious part of everyday life. From the late 19th century until the 1950s the majority of home furnaces in the U.S. used coal. During the 1950s, home heating began a conversion to natural gas because it was less expensive than coal. When home heating with coal ended, any residual concerns about coal were out of sight and out of mind. Modern technologies succeeded in minimizing many of coal's visible and untoward effects on the environment and controlling some of the worst and most immediate health effects. Significant improvements in pollution control and health protection have been realized, especially over the past 40 years as a result of hard fought legislative and other regulatory initiatives like the Clean Air and Clean Water Acts.

The obvious benefits of affordable, reliable energy at the flip of a switch, including support for the health care industry provided by Iowa's coal based energy grid cloud perceptions concerning coal's potentially adverse effects. It's understandable that many Iowans, especially given the high percentage (44%)[3] of Iowans living and working in widely dispersed, relatively isolated, small, tidy and secure rural towns, do not question the role of coal in generating electricity or trace the cost of any health concerns to coal combustion. Lack of awareness or attention to harms, current or potential, allows Iowans to accept the *status quo* including efforts to expand coal based electricity generation in Iowa.

Improvements have made today's coal related risks far less than in old London. However, while new plants tend to emit less toxins per ton of coal burned, the amount of coal burned continues to increase. Thus medical and public health researchers continue to shed light on coal's persistent health impacts. Emissions and disposal of coal waste products are increasingly implicated in contributing to yet other diseases of epidemic proportion beyond the obvious cardio-respiratory systems, including diabetes, cancers, and even the increasing numbers of young children diagnosed with a variety of cognitive behavioral disorders. These chronic diseases are likely induced and exacerbated by the complex interaction of coal emissions with a variety of environmental factors. For Iowa, adverse environmental exposures beyond those associated with burning coal and industrial sources include emissions from confined animal feeding operations (CAFOs) and intensive industrial agriculture.

To ascertain with certainty the exact contribution of specific coal plants or pollutants to the burden of disease in Iowa is costly and difficult given the multiplicity, persistence and accumulation of compounds produced when burning coal coincident with exposures to and interactions with other environmental factors. Direct methods, short of individual monitoring and complex source-apportionment analyses, are not readily available to comprehensively tease out and associate specific coal related factors with particular diseases or individuals. Yet, even modest contributions are likely to have measurable effects at the population level given the ubiquity of burning coal across Iowa. Thus the report's authors chose to review the available epidemiologic data, air quality monitoring data, and overlay these on maps of Iowa's coal burners considering likely emission plumes and prevailing roughly west-to-east wind patterns. In addition, the authors investigated relationships among coal combustion emissions and other sources of air and water pollution specific to Iowa.

Endnotes

1. Quoted in Peter Thorsheim, *Inventing Pollution: Coal, Smoke and Culture* from Arnold Marsh *Smoke. The Problem of Coal and the Atmosphere.* 1947 p. 264. Of interest, Marsh's book was reviewed in the Dec. 1948 *Journal of the American Public Health Association*.
2. Peter Thorsheim (2006). *Inventing Pollution: Coal, Smoke and Culture in Britain since 1800.* Ohio University Press. See also, David Stradling and Peter Thorseim. The Smoke of Great Cities: British and American efforts to control air pollution 1860-1914. *Journal of Environmental History.* Jan. 1,1999. Available through ProQuest. Accessed 7/18/10 at: http://findarticles.com/p/articles/mi_qa3854/is_199901/ai_n8833707/.
3. State Data Center of Iowa, population statistics revised 4/11/08. Accessed 7/18/10 at http://data.iowadatacenter.org/datatables/urbanrural/urmetrostpop18502007.pdf

Burning Coal in Iowa Today

"When the earth is sick and polluted, human health is impossible . . . . To heal ourselves we must heal our planet, and to heal our planet we must heal ourselves."

— Bobby McLeod (Koori activist, aboriginal)

Iowa leads the nation for it's production of wind energy. It is the first state in the US to have more than 10% of its total generated electricity from wind.[1] Nevertheless, Iowa continues to import and burn coal disproportionate to the size of its population. In contrast to the national average where about 50% of electric power is produced by burning coal, Iowa relies on coal for almost three-quarters of it's electricity generation[a] *(See Figure 1: EIA pie chart, Fuel Sources for Electric Power Generation, which compares Iowa and the US.)* On a per capita basis for coal consumption, Iowa ranks seventh in the country.[2] The Union of Concerned Scientists noted Iowa ranks 2nd as most dependent on coal imports as a share of total power production, making Iowa one of the most coal dependent states in the nation.[3] All this is so even though Iowa does not produce any coal of its own.[4]

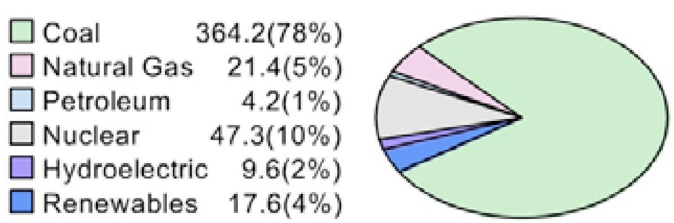
With only 3 million people, Iowa ranks 30th among the states in population, yet ranks 16th in coal power generation.[5] The electric power produced in Iowa's coal plants is sold to and consumed not only by Iowans but is exported to consumers in surrounding states.[6] Additionally, Iowa is home to several of the oldest, least efficient and most polluting coal burning power plants in the nation, those grandfathered in after passage of the Clean Air Act in 1977 and exempted from stricter emissions limits.[7] *(See Table 1: Iowa's Old Power Plants.)* This means that not only does Iowa have more power plants per capita than almost all states, but many of Iowa's power plants emit relatively more pollution per megawatt hour (MWH) of energy produced because of their age. Finally, fully ninety two percent of Iowans live within 30 miles of a coal plant–thus almost all Iowans are regularly exposed to the polluting elements within the emission plumes of coal burning facilities.[8]

Substantial scientific evidence demonstrates health and environmental harms at every stage of coal's life cycle, from the coal mine to the coal ash. No matter when, where, or how coal is mined, cleaned, transported, stored, burned, or its waste products disposed, coal based energy produces untoward and costly immediate and long term impacts on the environment and eventually human health. The evidence of adverse health impacts continues to grow as coal related pollutants accumulate in the environment and in human bodies. All grades of coal and the products of coal combustion affect all environmental and human physiological systems to a lesser or greater degree. Not withstanding, most official attention and concern continues to be given to assessing financial costs incurred by any regulation of coal, or the promotion of cleaner alternatives without attention to the very real health costs including medical care, suffering and loss of productivity due to related chronic illnesses.

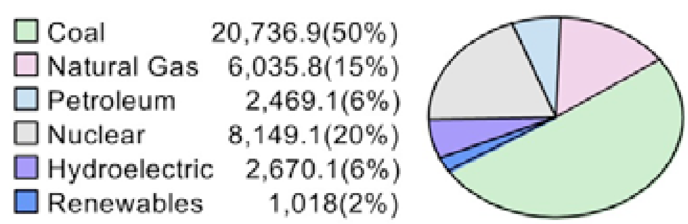
Increasing rates of asthma, cardio-respiratory disease, neurological disease and a host of other health conditions are all attributed to exposure to coal related air pollution. Such pollutants include mercury, fine particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic chemicals (VOC), and a long list of other harmful substances released into the environment from burning coal. When inhaled, these noxious products

Figure 1: EIA pie chart – Fuel Sources for Electric Power Generation

Fuel Sources for Electric Power Generation in Iowa in 2005



Fuel Sources for Electric Power Generation in the United States in 2005 (trillion Btu)



Source: U. S. Energy Information Administration
http://apps1.eere.energy.gov/states/electricity.cfm/state=IA#electricity

[a] Note: List and available details of all the coal plants in Iowa can be found at www.coaliniowa.org/

Table 1: Iowa's Old Power Plants

Site	US Age Rank	Built	Electric Produced MWH
Dubuque	6	1941	388,339
Lansing	23	1948	1,723,713
Walter Scott	118	1954	10,094,706
Geo Neal North	298	1964	6,653,037
Burlington	359	1968	1,317,632
Geo Neal South	518	1979	4,897,414
Ottumwa	538	1981	4,073,096

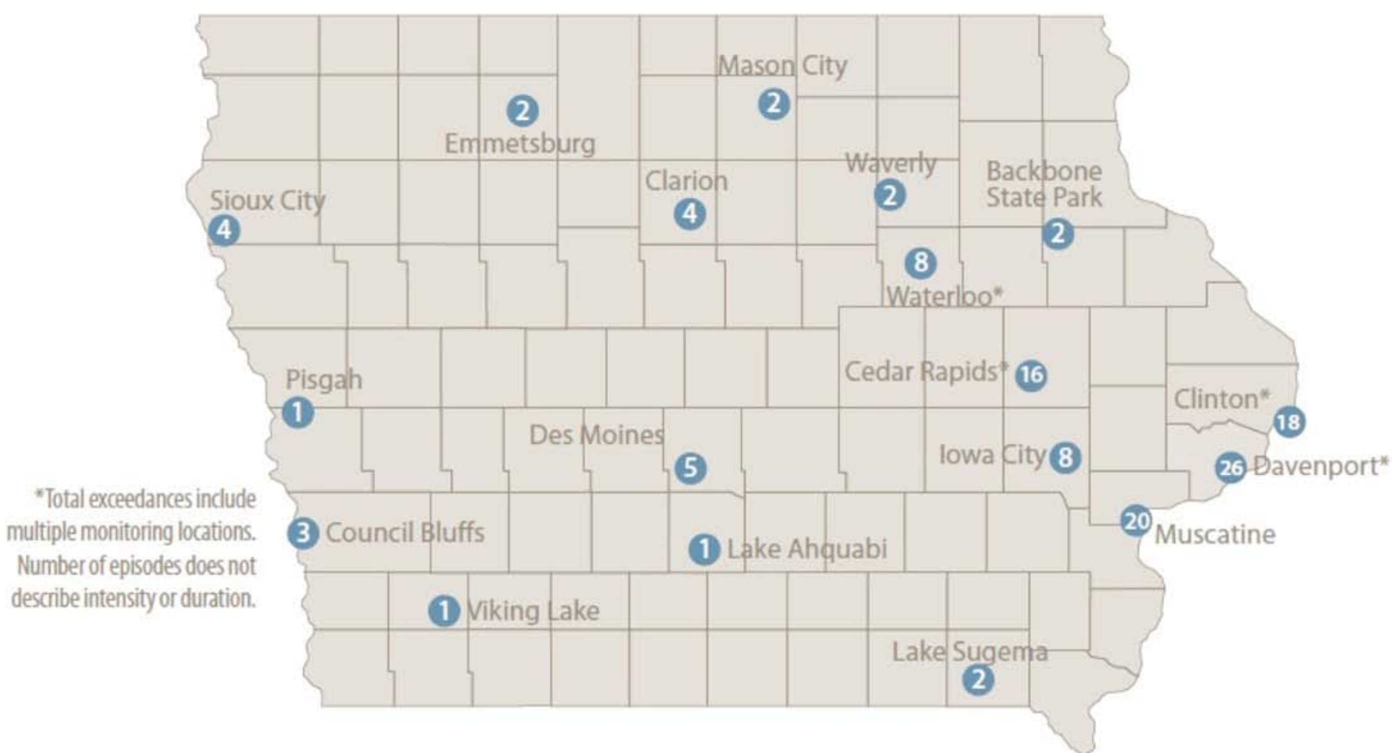
damage the respiratory, cardiovascular, and nervous systems and contribute significantly to four of the top five leading causes of death in the US: heart disease, cancer, stroke, and chronic lower respiratory diseases. In fact, burning coal contributes to or exacerbates many of the most significant public health problems faced today all around the world.[9]

Technologic improvements have been installed by coal industries to lessen the amount of hazardous substances released, yet many millions of US citizens, including Iowans, continue to be exposed regularly to coal based pollutants that exceed federal standards. The Iowa Division of Natural Resources (DNR) noted, "from 2007 to 2009, air pollution levels, [many of them as a result of contributions from Iowa power plants], exceeded public health thresholds 125 times at sites across Iowa – up 33 percent from the previous reporting period. Most of those recorded exceedances came from high levels of fine particles."[10 11] *(See Map 1: Days Exceeding Air Quality Standards.)*

Furthermore, the DNR reported that in 2010 by March 23, monitoring sites failed to meet 24-hour standards for PM, one of the many emissions' components of burning coal, 55 times. To date, only a few of the known components in coal plant emissions that have known or suspected adverse environmental and health impacts are even monitored, let alone, regulated. While scientific awareness of potential harms induced by exposure to coal combustion products continues to grow, public awareness and the ability to monitor or intervene in the production of coal related environmental toxic elements remains limited.

Given these serious concerns, members of the Iowa Chapter of Physicians for Social Responsibility, with support and guidance from the faculty of the University of

Map 1: Days Exceeding Air Quality Standards



Source: State of the Environment 2010, Iowa DNR, p. 15 http://www.iowadnr.gov/files/2010report.pdf

Iowa Geography Department, the University of Northern Iowa Health Division of the School of Health, Physical Education and Leisure Services, the staff of the Plains Justice Legal team, and members of the Re-Amp Network set out to more clearly assess and understand the role of coal based energy production and its impacts or effects on the health of Iowans: the known, suspected, and potential. This report is the result of that investigation.[12]

Endnotes

1. American Wind Energy Association. U.S. Wind Industry Annual Market Report April 8, 2010. Accessed 7/17/10 at http://www.awea.org/newsroom/releases/04-08-10-U.S._Wind_Industry_Annual_Market_Report.html
2. Energy Statistics. Coal Consumption per capita by state, most recent. Accessed 6/26/10 at http://www.statemaster.com/graph/ene_coa_con_percap-energy-coal-consumption-per-capita
3. Union of Concerned Scientists. Burning Coal, Burning Cash: Ranking the States that Import the Most Coal. Accessed 7/17/10 at http://www.ucsusa.org/clean_energy/technology_and_impacts/impacts/burning-coal-burning-cash.html and the page specific to Iowa: Accessed 7/17/10 at http://www.ucsusa.org/assets/documents/clean_energy/UCS-BCBC-factsheet-Iowa.pdf
4. Iowa does have small deposits of bituminous coal, but it has a high sulfur content and runs afoul of the Clean Air Act. Given all the associated costs, this small amount is not considered "recoverable" at this time.
5. Source Watch. Existing Coal Plants in Iowa. Data assembled from the Energy Information Administration. Accessed 7/17/10 at http://www.sourcewatch.org/index.php?title=Category:Existing_coal_plants_in_Iowa
6. The exact amount of electricity produced in Iowa whether from coal, wind or natural gas, sold outside the state is difficult to ascertain likely because of corporate privacy rights. The closest estimate is that about 43% of power produced in Iowa is sold elsewhere (personal communication with Nicole Shalla of Plains Justice, http://plainsjustice.org). MidAmerican Corporation's surplus electricity production, at times exceeds by 40% the normal demand of its 770,000 Iowa customers and is sold out of state, noted on a blog titled Legalectric by Carol Overland of Overland Law Office. Accessed 7/17/10 at http://legalectric.org/weblog/4970/. Also, see Teresa Galluzzo and David Osterberg. A Windfall of Green Energy: Iowa's Growing Generation of Wind-Powered Electricity. Iowa Policy Project. 2009. Accessed 3/10/10 at http://www.state.ia.us/government/governor/energy/Renewable_Energy/Docs/090413-windproduction.pdf
7. Courtney Abrams. America's Biggest Polluters: Carbon Dioxide Emissions from Power Plants in 2007. Environment Iowa Research and Policy Center. Nov. 2009. Note: Environment Iowa no longer operates in the state, but an identical report was put out by Environment America (the parent organization) This report was accessed 7/17/10 at http://cdn.publicinterestnetwork.org/assets/62514040f1134baf06e843fb233cd3ca/EA_web.pdf.
8. Calculated by noting the location of each of Iowa's coal plants with estimated census counts surrounding each.
9. Clean Air Task Force (CATF). Dirty Air, Dirty Power: Mortality and Health Damage Due to Air Pollution from Power Plants. Report composed by Abt Associates. June 2004. Accessed 7/18/10 at http://www.catf.us/resources/publications/files/Dirty_Air_Dirty_Power.pdf.
10. Richard Leopold. 2010 State of the Environment. Iowa Department of Natural Resources. p. 14. Accessed 6/21/10 at http://www.iowadnr.gov/files/2010report.pdf.
11. For example, mercury, most of which comes from burning coal and which has been known as a neurotoxin for a very long time, remains unregulated. Also, coal ash which concentrates all the heavy metals found naturally in coal has yet to be regulated as a toxic substance.
12. For a more general discussion and overview of the health harms of coal across the nation, the reader is referred to Lockwood, Alan, K. Welker-Hood, M. Rauch, B. Gottlief. Coal's Assault on Human Health: A Report from Physicians for Social Responsibility. Nov. 2009. 64 pages. Accessed 7/18/10 at http://www.psr.org/assets/pdfs/psr-coal-fullreport.pdf. Also note: while the Iowa report does not address the health related concerns at the extraction end of coal's life cycle, it is important to realize some of these very real costs incurred at the front end. The Center for Disease Control (CDC) estimates that 12,000 coal miners died from black lung disease between 1992 and 2002. Coal mining leads the nation in fatal occupational accidents: from 1900--2006, a total of 11,606 underground coal mine workers died in 513 U.S. underground coal mining disasters. A number of researchers have also documented excess diseases endured by residents of communities in proximity to mining operations. Details of these concerns are material for other histories and reports.

Background

Coal Combustion Emissions

"Water and air, the two essential fluids on which all life depends, have become global garbage cans."

— Jacques Cousteau

While much public discourse about coal emissions currently focuses on its release of carbon dioxide (CO_2), coal's more immediate and direct threats come from the products of combustion released to the environment: Nitrogen Oxides (NO_x), Sulfur Dioxide (SO_2), mercury, fine particulate matter (PM) along with a host of other toxic trace materials. *(See Table 2: Toxic Substances Released When Burning Coal.)* As an energy resource, coal comes in various levels of "purity" or grades of energy from the most dense, high energy content anthracite coal, to bituminous, sub-bituminous and lignite coal. Some coal naturally contains more or less sulfur or other impurities.[1] *(See Table 3: Coal Types & Energy Content.)* Regardless of type, all coal produces essentially the same products of combustion in greater or lesser amounts. For the purposes of assessing general impacts on human health, differences between coals are not significant. Regardless of their source, most of pollutants specific to coal have long been understood as harmful to humans and the environment.

Table 2: Toxic Substances Released When Burning Coal

- Nitrogen oxides, sulfur oxides, fine particulates ($PM_{2.5}$), volatile organic compounds and…,
- Over 67 Other Toxic Chemicals** including (but not limited to):

Antimony	Arsenic	Barium
Chromium	Copper	Lead
Manganese	Mercury	Nickel
Vanadium	Zinc	Hydrochloric acid
Hydrofluoric acid	Sulfuric acid	Ammonia
Selenium	Cadmium	Thallium
Other hydrocarbons		

**all of which can cause cancer and neurological problems

Since the Clean Air Act of 1970, the EPA has had upper limits standards for the amounts of NO_x, SO_2 and PM that can be released to the environment. The standards are designed to include a margin of safety to protect public health, including the health of sensitive populations like asthmatics, children, elders, those with chronic diseases, and those who labor outdoors. This law also requires air monitoring for compliance with these standards. When pollutant levels are higher than allowed by the standard, the area is said to be in non-attainment. Persistent non-attainment status can bring sanctions for the state, industry, or area of concern.

Table 3: Coal Types & Energy Content

No two coals are exactly alike: existing quantities, ease of access, heating value, sulfur, and other impurities vary:

Type	Carbon Energy Content
Anthracite	86 to 98%
Bituminous*	45 to 86%
Sub bituminous	35 to 45%
Lignite**	25 to 35%

*Most plentiful, used in Steel, Industry, & Electricity
**Mainly Used for Electricity Generation

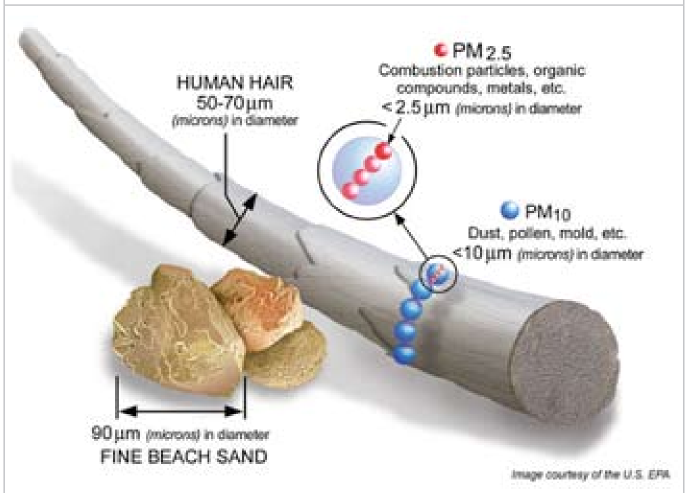
The Clean Air Act and the National Air Quality Standards (NAAQS) coupled with their review and upgrades every five years have brought decided improvements over earlier levels of risk.[2] However, there is room for much more improvement in protecting the public's health. According to the American Lung Association and others, pollution from coal-fired power plants is estimated to be responsible for nearly 24,000 premature deaths,[3] 21,850 hospital admissions, 554,000 asthma attacks, and 38,200 non-fatal heart attacks every year.[4] The corresponding analysis applied to Iowa estimated burning coal cost Iowans 40,988 lost work days, 333 hospitalizations and 7,322 asthma attacks every year, 412 of which are so severe they require emergency room visits.[5]

Given the variety of stakeholders and the corresponding economic issues, significant controversies exist over the adequacy of air quality standards, the costs, intensity and adequacy of the monitoring process, and enforcement of sanctions for repeated episodes of non attainment. Strengths and weaknesses of standards that cover large areas or are designed to measure annual averages, versus 24 hour concentrations, or levels found during discrete episodes of pollution releases are the gist of many questions posed by industry, academia, and public health experts. These details are beyond the scope of the current study.

Fine Particulate Matter

Fine particulate matter (PM), especially $PM_{2.5}$, refers to extremely small[6] (visible only by an electron microscope) particles that are 2.5 microns in diameter or less, or just 1/30th the width of a human hair. *(See Figure 2: How Small is PM?)*

Figure 2: How Small is PM?

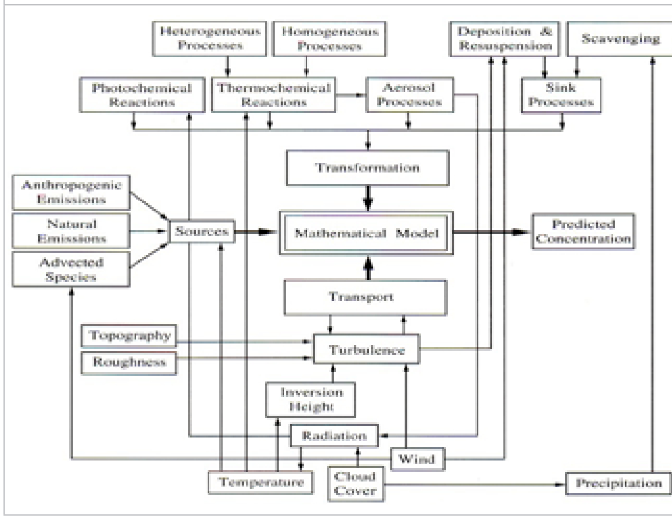


Source: http://www.epa.gov/nheerl/research/pm/research_area05.html

The composition of particulate matter is extremely variable and includes both solid particles and liquid droplets (excluding water droplets) found in outdoor air as a result of many combustion processes. Fine particulate matter may be emitted directly into the air or can form secondarily from pollutants that react with each other once in the atmosphere. The major components of PM are metals, ions (sulfate and nitrate), organic compounds, quinoid stable radicals of carbonaceous material, minerals, reactive gases, and materials of biologic origin.[7]

Because of their extremely minute size, fine particles can remain suspended in the air and travel very long distances from their source–for example, coal pollutants found in air along the US west coast have been traceable to sources in China.[8] Modern coal plants with tall stacks allow emissions to generally disperse over large areas depending on weather and wind conditions, thus diluting the quantity falling in any one location and complicating resolution of its source. On still or mildly breezy days PM can be expected to fall more quickly or intensely onto the area immediately surrounding a power plant, affecting most those who live closest.[9] To realize some of the inherent difficulties in assessing source and transport of $PM_{2.5}$, *(See Figure 3: Structure of Atmospheric Chemical Transport)* demonstrating the variables that determine where and how these and related tiny pollutants are transformed and transported.

Figure 3: Detailed Structure of Atmospheric Chemical Transport Models



The sources for fine particle emissions include all types of combustion from motor vehicles, power plants, wood burning, and some industrial processes. Nationally, electric generating plants are considered to be responsible for about 19% of the fine particulate matter released into the atmosphere, whereas in Iowa they account for about 25%. Correct and consistent reporting of PM emissions by individual sources is admittedly a continual challenge and approximations of the amount released vary to some degree by observer and technique used to quantify such amounts.[10] Trust in the accuracy of emissions reporting has to be somewhat conditional because most of the emissions data available are from self-reporting sources. Independent verification of available data is not generally done–there exists no consistent or mandated mechanism available to check the veracity of information provided to sources like the DNR, EIA or EPA. Iowans rely on the industry to be responsible and reliable in monitoring and reporting its own emissions.

Fine Particulate Matter

- Fine particles are efficient carriers allowing toxins direct entry via the lungs into the blood stream.
- PM_{10} and $PM_{2.5}$ arise from combustion, metal smelting, road dust, windblown soil and secondarily from chemical reactions involving SOx, NO_x, VOCs & other gases in the air.
- These particles are composed of elemental and organic carbon, biologic compounds, metals like iron, copper, nickel, zinc, vanadium, lead, and mercury among , others.
- The formation of fine PM may involve reactions in the atmosphere that take place over days and weeks when the chemicals from more than one plant combine many miles from original emission sites.
- Most fine particles contain toxic materials that can contribute to organ damage, cancers and immunologic disorders.

NO_x and SO_2

Combustion of most fuels, not just coal, produces oxides of nitrogen or NO_x, which is oxidized in the atmosphere to NO_2. In contrast to the less specific sources of emissions producing NO_x, sulfur dioxide (SO_2) is primarily generated from the combustion of sulfur-containing coal and oil, diesel fuel. While amounts of SO_2 and NO_x emitted by coal fired power plants have been declining significantly over the past two decades,[11] coal-fired power plants still emit 73% of total U.S. sulfur dioxide pollution[12] and 18% of total nitrogen oxides every year. For Iowa, given the relatively high number of off road farm vehicles burning sulfur containing diesel, the percentage of SO_2 from coal plants is about 58%. *(See Maps 2 and 3 from the EPA for relative emission densities of NO_x and SO_2 in Iowa.)*

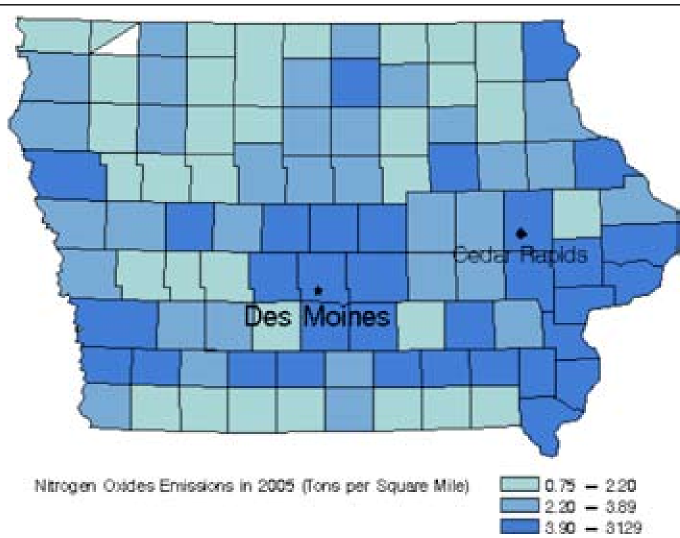
Most NO_2 is formed in the air through the oxidation of nitric oxide (NO) emitted when fuel is burned at a high temperature. SO_2 and NO_2 can oxidized by water vapor to form sulfuric and nitric acid in the atmosphere which can then react with ammonia to form sulfates and nitrates, both of which are important components of ambient PM. If ozone (O_3) is present the conversion is very rapid. Nitrogen dioxide is the most stable and most abundant of NO_x compounds in the atmosphere. NO_x are related to increased risk of lower respiratory illness especially in children and increased risk of asthmatic reactions and infections in at-risk populations because of its effects on the immune system and alveolar macrophages. Consequently NO_x exposures contribute to increased emergency department visits and hospitalizations.

SO_2 can induce acute bronchospasm in asthmatic subjects at relatively low concentrations and after very short, mere minutes, exposures. This fact is particularly troubling for asthmatics who find themselves exercising outdoors when the level of SO_2 is even briefly elevated–this would include those with outdoor occupations. Both NO_x and SO_2 contribute to the formation of particulate matter. Of concern to Iowa which produces and uses an abundance of ammonia, NO_x react with ammonia, moisture, and other compounds to form $PM_{2.5}$.

Mercury

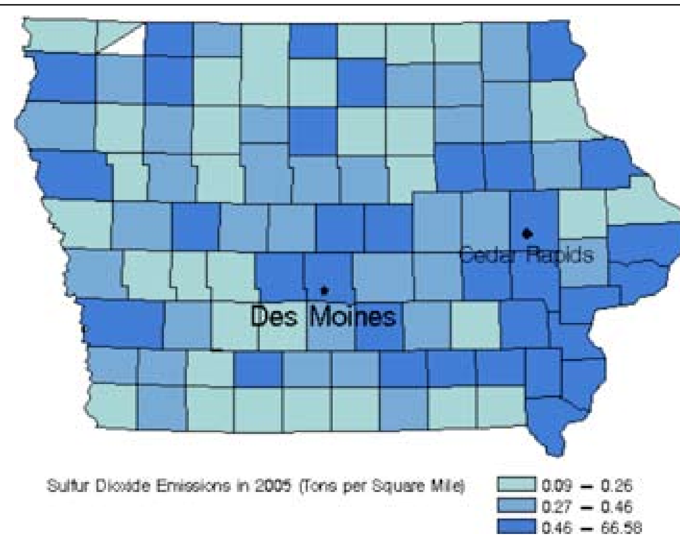
Mercury, found in coal containing rocks, is a natural element that cannot be made or destroyed by humans. When coal is burned, it releases mercury into the atmosphere. Burning coal is the primary source of human caused environmental mercury. This mercury falls to the earth in rain, and runs into lakes, rivers, and streams. In the water, bacteria transform this mercury into the readily absorbable and toxic form, methylmercury. Consumption of fish tends to be the main route for human exposure to mercury. Fish become contaminated when they consume the methylmercury, which then accumulate and travel up the food chain to be consumed by humans, of particular concern: women and children.[13] *(See Figure 4: Mercury in the Environment.}*

Map 2: Relative Emission Density NO_x tons per square mile



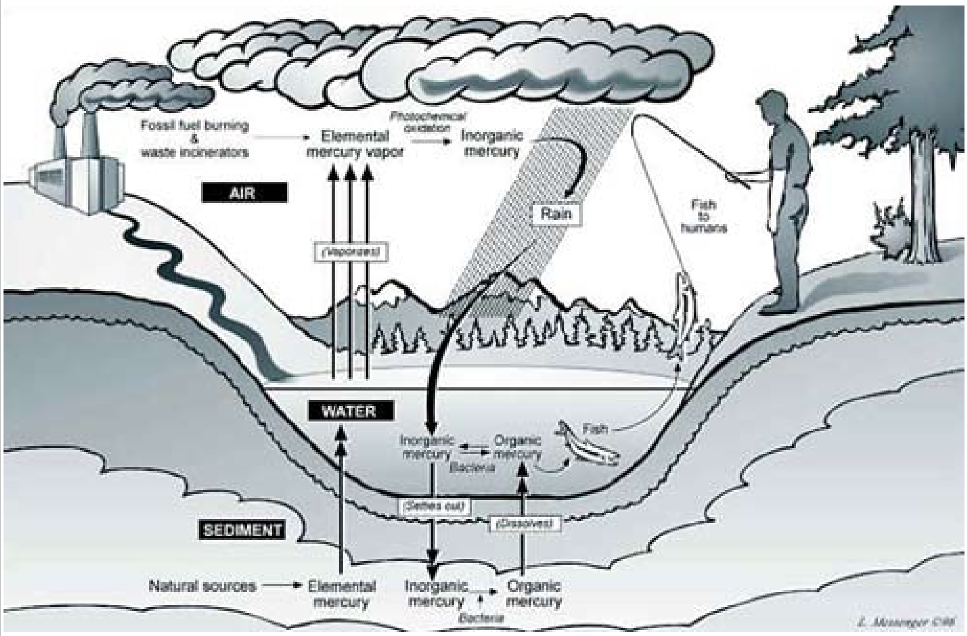
Source: http://www.epa.gov/cgi-bin/broker?_service=data&_debug=0&_program=dataprog.dw_do_all_emis_2005.sas&pol=227&stfips=19

Map 3: Relative Emission Density SO_2 tons per square mile



Source: http://www.epa.gov/cgi-bin/broker?_service=data&_debug=0&_program=dataprog.dw_do_all_emis_2005.sas&pol=228&stfips=19

Figure 4: Mercury in the Environment



Source: http://people.uwec.edu/piercech/hg/mercury_water/cycling.htm

According to the EPA estimates, over 50 tons of mercury are released nationwide annually[14] putting 630,000 babies at risk each year of developing serious mercury-related health effects.

In 2005, the EPA mercury road map noted additionally, "there is evidence in adults that the organic form of mercury, methylmercury, also affects other systems. European studies suggest that mercury poisoning is associated with increases in deaths from heart disease, which is the top killer in the United States. Other studies suggest that "prolonged exposure to methyl-mercury, especially at higher levels, can harm the heart, kidneys, and immune system."[15]

Despite increased efficiency in power plants and gradual reduction in emissions for amount of coal burned, the total number of advisories in the U.S. for mercury increased from 3,080 in 2006 to 3,361 in 2008. Of all fish advisories, 80% were based at least partly on mercury. As of 2008, 27 states, including Iowa and all states surrounding Iowa,[16] have statewide advisories for mercury in freshwater lakes and/or rivers. Thirteen states have statewide advisories for mercury in their coastal waters, and one state has a statewide advisory for mercury in marine fish.[17]

Other Heavy Metals

Given what is known about the variety of hazardous air pollutants (HAPs) including the heavy metals emitted by coal plants, the authors sought to report on studies of corresponding measurable health effects. As noted earlier, coal naturally contains a long list of toxic chemical that are released when burned. *(See Table 2: Release of Toxic Substances.)*

However, this issue is virtually impossible to address currently because according to an EPA Report, released at the end of 2009[18], "information on a unit's permitted emission limits, and monitoring, record keeping, and reporting requirements for all HAP emissions are not available from any single source." The report goes on to assert that

> ...there are no readily available sources for coal- and oil-fired electric utility steam generating units of fuel amounts received, fuel sources, fuel shipment methods, and results from previously conducted fuel analyses for each individual coal and oil shipment received during the preceding 12 months before this ICR, or for any previously conducted (since January 01, 2005) emissions test results that will provide data for emissions of a variety of pollutants, including: particulate matter (PM), particulate matter smaller than 2.5 microns (PM2.5), sulfur dioxide (SO2), *hydrogen chloride/hydrogen fluoride/hydrogen cyanide (HCl/HF/HCN), metal HAP (including compounds of antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), lead (Pb), manganese (Mn), and selenium (Se)), mercury (Hg), total organic hydrocarbons (THC), volatile organic compounds (VOC), and carbon monoxide (CO)* [authors' emphasis].

Finally, while noting that some data for some pollutants is available at times, the complete extent of the data fields requested under the EPA survey requirement is not available in a consistent and usable format. The 2009 EPA report lists a number of problems in accessing even the data that does exist. In response to this critical inadequacy of record keeping and reporting, a lawsuit against the EPA was filed late in 2008 by Natural Resources Defense Fund, Physicians for Social Responsitility, and others . The EPA is now obligated to develop emissions standards and has announced that the proposed rules will be promulgated by late November 2011[19].

After the Burning: Coal Combustion

About 131 million tons of coal ash[20], also refered to as coal combustion waste (CCW) is generated in the U.S. each year,[21] making it the nation's second largest waste stream after municipal solid waste. Iowa's coal plants produce 20,000 to 30,000 tons of coal ash annually.[22] Within the ash, the heavy metals and toxic components, including radionuclides found in coal prior to combustion are far more concentrated than in the source coal before it is burned.

Coal combustion waste is a major human made environmental source of many concentrated heavy metals considered toxic and known to cause neurological problems and a variety of cancers. A GAO 2009 report noted that between 2000 and 2006, the power industry reported depositing into surface impoundments and landfills combustion residuals containing more than 124 million pounds of six of these toxic pollutants (arsenic, chromium, lead, nickel, selenium, and thallium).[23] A single power plant that operates for 40 years will leave behind 9.6 million tons of toxic waste.[24]

In Iowa, this waste stream is disposed of in a variety of ways, including sanitary landfills, industrial re-use, road building, fill for construction projects, and filling of abandoned mines and quarries. Without proper precautions, land-disposed CCW can leach toxic heavy metals into groundwater and surface water. Despite the number of toxic elements contained in CCW, few regulations exist regarding its safe disposal or monitoring of its distant dispersal into ground water. In 2000 EPA began to formulate safeguards for coal ash disposal, but to date has not yet done so. Similarly, in Iowa, the DNR began to design new rules, but has also stalled in the process waiting to see what transpires in the EPA.

Despite what is known about the hazards of CCW, there is no federal designation of it as a toxic material, waste sites are not formally tracked, and there are no nationally enforced standards for its safe disposal. In the GAO's own report, sent on Oct. 30, 2009, the office asserts:

> The exact number of CCR surface impoundments at utility coal fired power plants is not known: No industry organization or government agency tracks this information. However, industry groups and federal agencies have obtained estimates through

Map 4: Recognized Coal Combustion Waste Sites July 2010

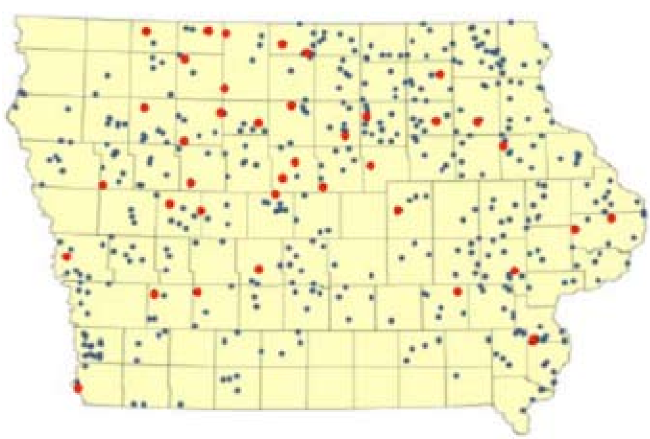
Source: Map of Iowa CCW Sites as compiled from Plains Justice, EPA, DNR, and Iowa Independent Sources. Note: locations for the Buffalo mine and the Goose Lake quarry are estimates. One of the Cedar Rapids Quarries were not mapped.

surveying coal-fired power plants as part of efforts to collect and analyze data on CCR disposal practices and state regulatory requirements.[25]

Across the country EPA has begun gathering data and assessing dangers posed by various coal combustion waste management processes. As of late 2009, proven cases of damage and surface water pollution containing high levels of toxic elements had been found in over 13 states with an additional 40 potential damage cases.

Map 5: 2006-08 Iowa Statewide Rural Well Water Survey (SWRL2) Arsenic Data

EPA's safe maximum contaminant level (MCL) is 0.01 mg/L. The dots indicate tested wells. The red dots indicate wells with arsenic levels exceeding the EPA MCL



Source: http://www.cheec.uiowa.edu/research/SWRL2%20results.pdf

Given Iowa's relatively less stringent monitoring and regulatory system CCW is also imported from other states, including those as far away as Indiana.[26] Similar to difficulties encountered in tracking other reliable and credible details regarding burning coal, the waste trail too is difficult to follow. Initial sources indicated that Iowa has 13-15 coal combustion waste sites. The authors of this report were able to identify 23 such sites *(See Map 4: Recognized CCW Sites,)*, while the GAO reports that Iowa has at least 43 surface impoundments for coal facilities.[27] Even with this question-able number, the GAO lists Iowa as having the third highest number of surface impoundments for coal combustion waste right behind Kentucky with 44. However, as noted above, the GAO indicates that their database is incomplete.

Iowa Wells

- 48% of Iowa's private wells show arsenic contamination.
- 8% of Iowa private wells exceed the Safe Drinking Water Act standard for public water supplies.

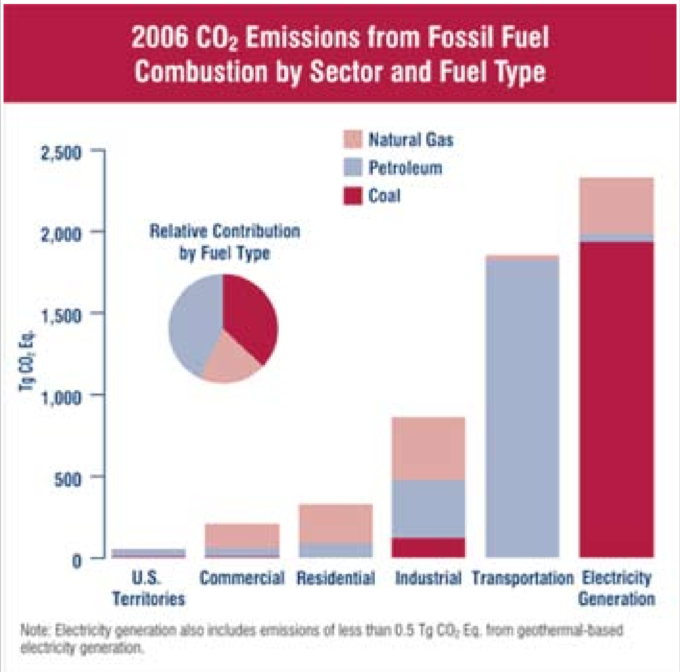
Evaluation of near or downstream water sources for contamination is not yet conducted in a routine fashion across Iowa even though almost one out of six Iowans use private wells as their source of drinking water many of which already have evidence of arsenic contamination.[28] *(See Map 5: Arsenic Levels in Private Wells.)* Since CCW quantities, locations and related data have not been systematically tracked or risks assessed, it is not possible currently to estimate adverse health effects arising from Iowa's coal waste management.[29] However even as air quality standards increase, other health risks can be expected to increase downstream if waste management is not adequately addressed. The amounts of concentrated pollutant discharges into Iowa's water from CCW can be expected to increase as scrubbers capture more of these toxic elements which will then continue to accumulate in the environment via landfill leakage instead of as air pollution.

Carbon Dioxide

Not to be overlooked, but important to keep in mind: the carbon dioxide (CO_2) emitted from coal fired power plants, is not yet subject to regulation. CO_2 is one of the most abundant, persistent, and powerful greenhouse gases. Coal plants together account for about 40% of U.S. CO_2 emissions.[30] *(See Fig 5: EPA CO_2 Emissions by Fossil Fuel Type.)* The important adverse health effects of CO_2 are due primarily to its effect on the atmosphere as a driver of climate change through warming the planet. As the climate is changing there are and will be increasingly dangerous changes in the earth's hydrologic cycles. In recent decades, Iowa and the Midwest are experiencing more precipitation and extreme weather events.[31] *(See Figure 6: Precipitation Changes in Iowa.)* Elsewhere there are more extreme heat waves, and alterations in local ecology including the distribution and ecological niches of disease vectors. When taken together, these changes bring about increased death, injuries, illnesses, and risks of important infectious diseases[32] [33].

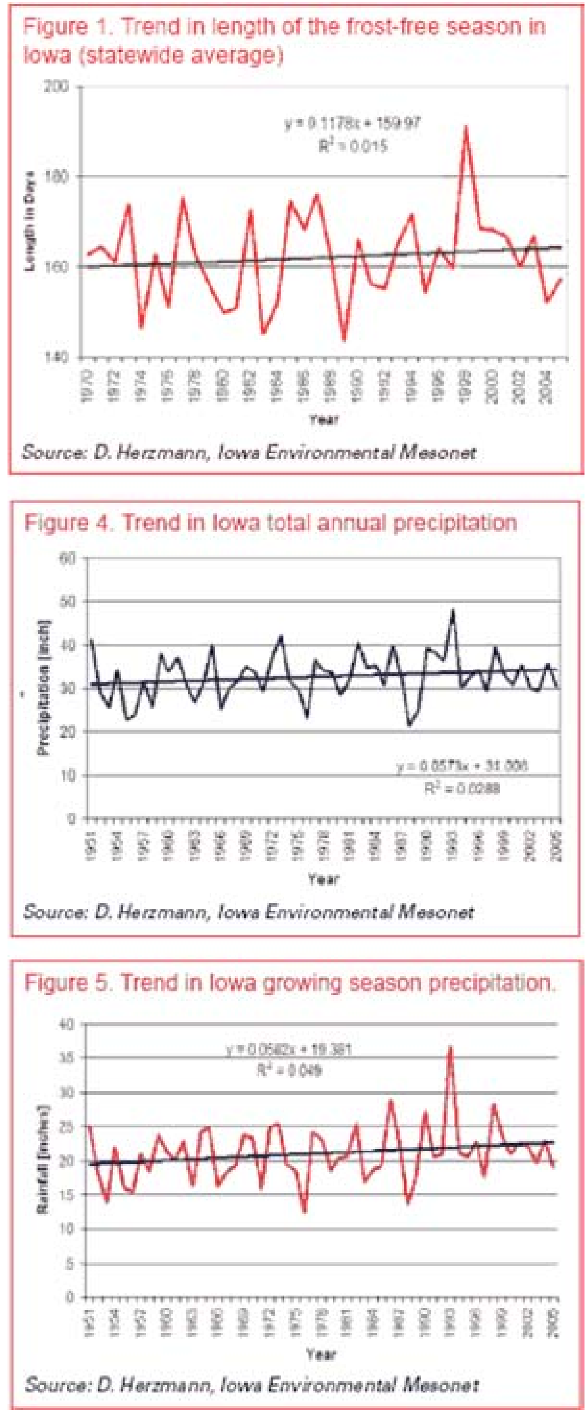
The earth's atmosphere already contains over 390 ppm CO_2.[34] Most scientists consider the upper limit of safety for our atmosphere to be closer to 350 ppm CO_2, a level which would provide a greater than 90% probability of staying within 2°C of pre-industrial global average temperatures. The atmosphere, in which the human species and agriculture have evolved, is rapidly approaching "peak capacity," defined as the safe or tolerable limit for greenhouse gases. CO_2 is the most abundant greenhouse gas. To maintain a climate that supports human health and adequate food produc-tion, the atmosphere can hold little more CO_2 or any of the other greenhouse gases generated by coal combustion before dangerously irreversible changes in global climate are induced.[35] Despite the insurmountable costs already experienced in Iowa due to flooding and the extreme tornados of 2008 and the consequences predicted by rising greenhouse gases, use of coal and the direct consequences on costs of energy is infrequently compared to the relatively low cost and high benefits of various efficiency or alternative energy scenarios.[36]

Figure 5: Climate Change Greenhouse Gas Emissions. Human-Related Sources and Sinks of Carbon Dioxide



Source: http://www.epa.gov/climatechange/emissions/co2_human.html

Figure 6: Precipitation Changes in Iowa
Global warming – impacts of climate change in Iowa.



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Burning Coal: Illnesses, Diseases of Concern–US and Iowa

"Just as there may be a time lag between [pollution] emissions and exposure, there may also be a time lag between exposure and [human or ecological] damages."

— US EPA, "Unfinished Business: A Comparative Assessment of Environmental Problems" 1987

Inhalation of SO_2, NO_X, $PM_{2.5}$ and other toxic atmospheric pollutants together or singly challenges health and contribute to the suffering and cost of acute and chronic disease across the country. These pollutants contribute to the billions of dollars spent by Iowans on chronic diseases like cardiovascular disease, asthma, and cancer each year. $PM_{2.5}$ and other ultra fine particles are too small to see, and too small to be collected by the protective anatomy of the upper respiratory system. The human respiratory system evolved to protect the body from soot and larger particles of dirt that occur naturally in the environment–not the many molecular pollutants proliferating since the modern industrial age. Until the last century the environment did not have the preponderance of manmade chemicals and industrially related fine particulate matter currently encountered essentially everywhere–humans have not evolved protections from these assaults.

Determining specific causality or any individual's risk when considering any specific coal plant is not a simple task. Risks vary on factors having to do with the individual, the individual power plant, and other environmental factors to which the person is exposed at home or at work. For any given coal plant, the amount and nature of particulate matter, nitrogen oxides, sulfur dioxide, heavy metals and/or other elements released by burning coal will vary depending on the age of the plant (older plants tend to have less effective environmental controls), the plant's capacity, the quality of the coal being burned, prevailing weather conditions, and the wind direction and force. Nevertheless, some relationships concerning each of these components, their mechanisms of action and impact on human health are known with certainty.

$PM_{2.5}$ is related to many adverse outcomes including sudden death, cardiovascular, and pulmonary disorders. Such microscopic particles can penetrate deeply into the lungs to trigger irritation of the airways, coughing, and difficulty breathing as well as contribute to reduced lung function especially in growing children. Fine and ultrafine particles not only penetrate deeper into the airways of the respiratory tract but in reaching the alveoli 50% are retained within the lung tissue. $PM_{2.5}$ aggravates asthma and chronic bronchitis, and also induce irregular heartbeats and heart attacks. $PM_{2.5}$ can contribute to some cancers by crossing the lung-blood barrier and entering the general circulation.[1] Investigators with the American Cancer Society noted in a prospective study published in 2002, that each 10-µg/m^3 elevation in fine particulate air pollution was associated with approximately a 4%, 6%, and 8% increased risk of all-cause, cardiopulmonary, and lung cancer mortality, respectively.[2]

For each of these concerns, the operative factors and mechanisms are only partially understood because the actual sizes and composition of PM in association with SO_2, NO_x vary greatly, depending on additional factors from place to place. The shape, composition and size of the airborne particles, and their surface area determine the potential to elicit inflammatory injury, oxidative damage, and other biological effects. While particle size does matter, particle composition seems also to be extremely important in the pulmonary inflammatory response to particulate air pollution. The surface area of the particle may also allow for chemical toxin transfer and an area for toxins to interact and form even more toxic compounds. Toxicologic research has shown that PM induces adverse cellular effects via several mechanisms: cytotoxicity through oxidative stress mechanisms, oxygen free radical generating activity, DNA oxidative damage, mutagenicity, and stimulation of pro-inflammatory factors.[3] [4]

Asthma, COPD

It is estimated that between 20 and 34 million people[5] [6], or, up to about 15% of the U.S. population have asthma, a disease long associated with inhaled allergens, irritants, pollutants, and weather extremes. This hyper-reactive airways disease is characterized by wheezing, coughing, chest tightness and shortness of breath. Asthma symptoms range from mild to severe and in extreme cases, asthma can be life-threatening. Beyond respiratory symptoms, impacts include lost work or school days, emergency department and hospital admissions, decreased lung function similar to that seen in chronic obstructive lung disease in smokers, and death.

People with asthma account for more than two million emergency room visits in the U.S., over nine million doctor's appointments, and more than 500,000 hospitalizations annually. More than 5,000 people, many between the ages of 5 and 34, die each year in the U.S. because of asthma. Although the frequency of smoking, one of the most potent risk factors, whether personal or second hand, has been steadily declining over the last decade, the percentage of people diagnosed with asthma (asthma prevalence) in the U.S. has doubled since 1979 making asthma a profound and expensive public health problem. Asthma is considered the fourth most prevalent chronic condition in adulthood.

While many factors can induce asthma symptoms, populations suffering with asthma are strongly correlated with air quality standards. Asthmatics are especially susceptible to fine ($PM_{2.5}$) and coarse (PM_{10}) particulate matter and SO_2 pollution including short acute exposures.[7] While some of the morbidity and mortality of asthma induced by almost any factor can be prevented or minimized by avoiding known provocative factors, the asthma sufferer has to be able to recognize early warning signs and be able to take appropriate action. For those who work outdoors and those most at risk, young children or elders, such preventive interventions may not be possible.

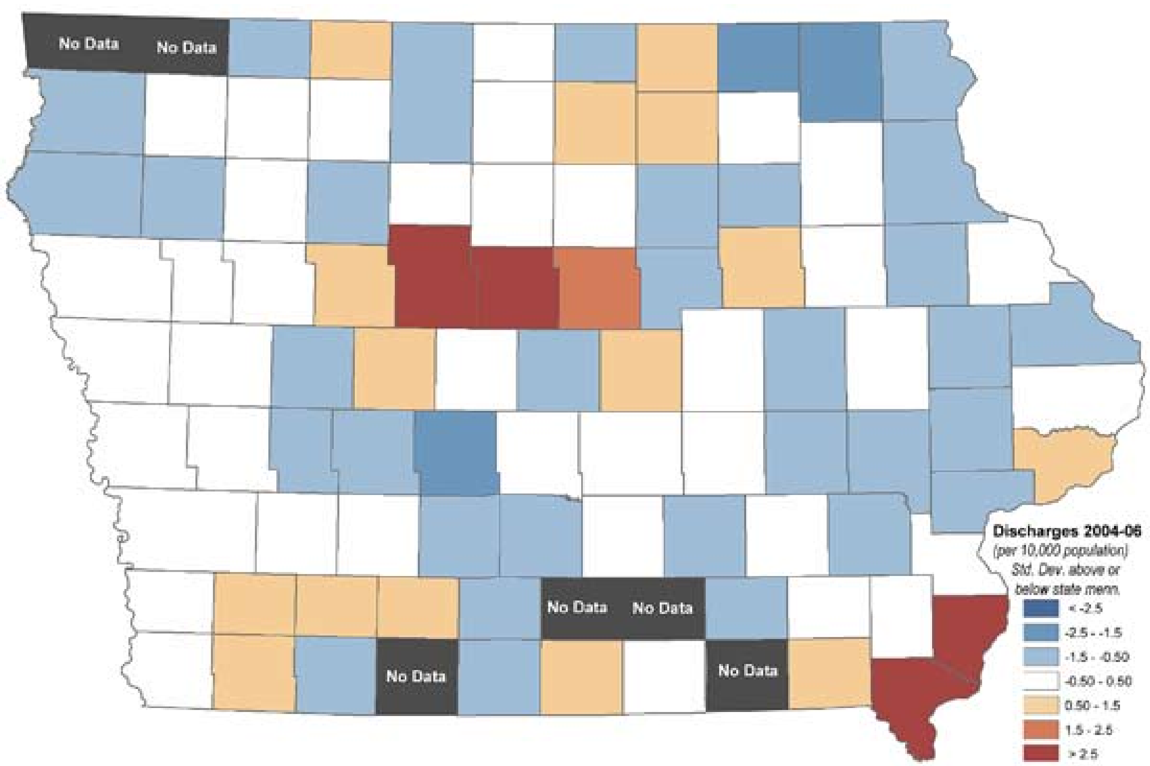
Depending on the frame of analysis, costs for health and lost productivity due to asthma in the U.S. are estimated to be $19.7 billion. Direct costs make up $14.7 billion and indirect costs such as lost productivity add another $5 billion.[8] Costs associated with asthma in Iowa totaled $116 million in 1994. Of the $116 million, direct medical expenditures were $66 million and indirect costs for asthma were assessed at $50 million. We can safely assume that these costs have only gone higher over the intervening years.

In 1999 and in the years since, asthma in Iowa has been reported at an overall steady prevalence of more than 200,000 Iowans, but the rates are not uniform or random across the state.[9] *(See Map 6: Iowa Asthma Hospitalization Rates.)* Asthma is responsible for the death of about 53- 80 Iowans each year. An Iowa DNR summary indicates that for each direct asthma death, it contributes to two more; and similarly asthma is noted to be a contributing factor for hospitalizations attributable to other causes.[10] Diagnosed asthma among Iowans, includes about 148,000 -150,000 adults, the rest are children of varying ages. Unfortunately, some studies suggest that as much as half of all asthma remains undiagnosed.[11]

According to the Iowa Department of Public Health (IDPH), Iowa adults with the highest asthma prevalence rates are: women, especially minority women; low-income Iowans; high school dropouts; those with chronic poor health overall; current and former smokers; and the obese. Interestingly, included in the adult populations with the highest number of cases of asthma (as opposed to the highest rates) are the "never" smokers--although current or ever-smoked have higher rates than never smoked. For none of the IDPH reports is exposure to coal, fossil fuel

Map 6: Iowa Asthma Hospital Discharge Rate, 2004-2006

Map shows number of standard deviations each county hospital discharge rate is above or below the state mean. One standard deviation = 7.1 cases/10,000 population.



emissions, or industrial pollutants included as potentially causing or exacerbating asthma. Nor are these factors addressed in any way in plans or consideration for care or prevention.

Despite what is known about the relation between asthma and pollutants released by fossil fuel combustion, essentially all problems or solutions identified had to do with personal behavior patterns, indoor pollution, or outdoor allergens. There is an occasional mention of generic “air pollution.” Any industrial contributions to this common and debilitating disease are rendered completely opaque.

Heart Disease and Stroke

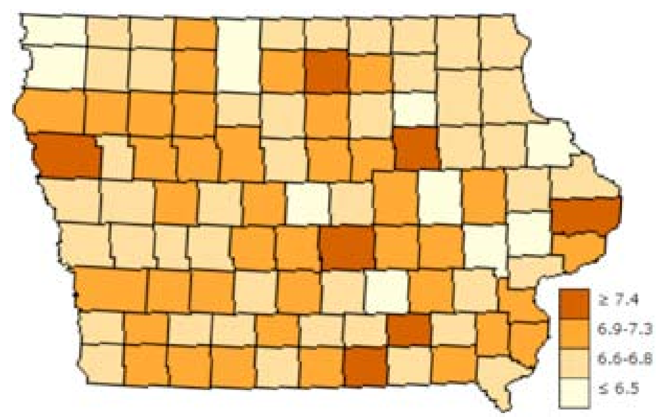
Heart disease and stroke remain major killers of Iowans and U.S. citizens in general. They are leading causes of disability, hospitalizations, and health expenditures. Over 31% of all deaths in Iowa in 2007 were attributed to cardiovascular diseases. Additionally, during the same year, 90,000 Iowans suffered heart attacks and over 60,000 experienced a stroke. These problems accounted for 48,500 hospitalizations and $1.3 billion in associated health care charges. As with asthma, there are disparities regarding the incidence and prevalence of cardiovascular disease patterns between white Iowans and those of minority populations.[12]

The standard investigations identifying associated factors for serious cardiovascular disease list personal life style factors like cigarette smokers, minimal physical activity, poor eating habits, elevated blood pressure and cholesterol, and diabetes or obesity. Again, as with asthma, within the literature from the IDPH, there were no indications of exposure to coal combustion, air pollution, fine particulate matter or any other environmental pollutants as potential risk factors despite the large and growing body of literature demonstrating this association. Regional differences in incidence and prevalence are likewise overlooked.

Type II Diabetes–Insulin Resistance

Rates of obesity and diabetes have achieved epidemic proportions across the country and around the world. Iowa is no exception. In fact, the percent of obese Iowans (BMI more than 30) rose from 13% in 1990, to 25% in 2005 and to almost 39% in 2009.[13] While most research focuses on exercise and diet as the main causative factors for both obesity and diabetes, there is growing evidence that air pollution too can increase insulin resistance and contribute to both Type I (insulin dependent) and Type II (non-insulin dependent) diabetes. See Map 7: Age Adjusted Estimates of Diabetes, for a county based picture of Iowa’s growing diabetes problem A number of authors have examined the relationship between inhaled pollutants, NO_2, PM_{10} and $PM_{2.5}$, polycyclic hydrocarbans (associated with coal combustion), among others, and the development of significant immune mediated illness like diabetes. Gomez-Mejiba, *et al.* reviewed the likely mechanisms of oxidative stress, that once started in the lungs, can go on to induce inflammatory responses elsewhere.[14] A Canadian study[15] found that exposure to NO_2 air pollution was associated with higher levels of diabetes in women, but not men. This study did not include other air pollutants. An interesting Iranian study found that air pollutants were associated with the development of insulin resistance in children.[16]

Map 7: 2007 Age-Adjusted Estimates of the Percentage Adults Diagnosed with DM
Centers for Disease Control and Prevention: National Diabetes Surveillance System



Source: Centers for Disease Control and Prevention: National Diabetes Surveillance System http://www.cdc.gov/diabetes/statistics/index.htm

Iowa’s Populations of Special Concern

“Somehow the forces of justice stand on the side of the universe, so that you can’t ultimately trample over God’s children and profit by it.”

— Martin Luther King Jr., “The Birth of a New Nation,” April 7, 1957

Minorities, People of Color

The image of Iowa as a rural state tends to obscure the fact that Iowa has more industry than farms.[17] In several Iowa communities, including Waterloo, Cedar Rapids and Muscatine, the emissions coming from stacks and pipes from the coal plants closely mingle with those of other industrial operations. Similar to other industrial areas of the U.S., Iowa's industries tend to cluster together and be surrounded by poor neighborhoods with substandard housing occupied disproportionaly by low income minority populations. These same neighborhoods can have high populations, yet can be health care shortage areas. *(See Map 10, Urban area health care shortage areas are designated in red.)* Populations in such areas represent those of diverse cultural backgrounds and educational levels, who vary in their health seeking behaviors and ability to access needed appropriate health services.

Even though Iowa has a relatively small proportion of African Americans, Hispanics and other people of diverse origin, about 6% total, there is concern about their disproportionate health risks. Across the country, African Americans are disproportionately affected by environmental pollution much of which originates in burning coal and other fossil fuels. It was noted in 2002 that 68% of African Americans live within 30 miles of a power plant and by comparison, only about 56% of the white U.S. population lives within 30 miles of a coal-fired power plant. Asthma mortality is rising in African American communities even though other rates of mortality are on the decline across the states.[18]

Lung Disease in Children

- Children & teenagers in communities with higher levels of air pollution are more likely to have diminished lung function.
- The lung effects on children are similar to those that occur when children live in the home of a mother who smokes.

Source: California Environmental Protection Agency

Such concerns have been and continue to be apparent in Iowa.[19] When the coal plants were being proposed in Waterloo and Marshalltown, critics noted that both sites were close to minority populations.

> "The intention of placing them in the demographics of our most at-risk individuals, Marshalltown with its large Latino population, and Waterloo with its greater number of African Americans may have the appearance of providing employment, but at great cost to the health of the participants, as well as the families in the proposed areas."[20]

Nationally, asthma affects African Americans at a 36% higher rate of incidence than whites, and asthma hospitalization rates for blacks, at 35.6 admissions per 10,000 people, are three times the white hospitalization rate of 10.6 admissions per 10,000 people. African Americans also tend to die of asthma at three times the rate of whites.[21] The death rate from asthma among blacks is 38.7 deaths per million people while that for whites, is 14.2 deaths per million.

Even though African Americans constitute a small Iowa minority they are among those with the highest rates of asthma in Iowa, especially African American women and children. African Americans constitute only 2.8% of Iowans, yet they account for 14% of the emergency department (ED) visits for asthma. Rates of ED visits are going up for both white and African American Iowas, but at different rates. From 2003 to 2008 Caucasian Iowan visits increased 3.5% per year while that of African American Iowans increased 5% per year. [22] Asthma hospitalization rates among African-Americans of Black Hawk County, the area with the poorest air quality, are 2.5 times higher than the overall county average, and 40% higher than the state average hospitalization rates for all African Americans in Iowa.[23]

Children

Asthma prevalence and morbidity are higher in children than adults; and asthma is the most common chronic disease of childhood. It is estimated that 6.2 million children in the U.S. suffer from asthma.[24] Of the 200,000 Iowans with asthma in 1999 over 40,000 are under age 18. Reported rates of Iowa children with asthma vary greatly. According to the IDPH, at least 12 percent of children living in rural Iowa have asthma, and some areas appear to have as much asthma as children in inner cities.[25] The 2005 Iowa Youth Risk Behavior Survey estimated 14.4% of Iowa High School youth have asthma. Inhalation of fine particulates is detrimental to lung development in growing children.

About a third of Iowa's children attend schools in close proximity to coal plants–schools and plants operate within the same municipality. *(See Table 4: Iowa Schools Near Coal Plants.)* For any airborne pollutant children are at greater risk than adults.[26] Whereas, the average adult breathes over 3,000 gallons of air every day,[27] children with their higher respiratory rate, and generally greater level of physical activity, breathe more frequently and more air per pound of body weight, thus inhaling relatively more of the ambient air, including any air borne pollutants in their air space. For Iowa's children, asthma inducers include $PM_{2.5}$, NO_X, and SO_2 all of which are contributed from coal and other fossil fuel combustion for power generation, transportation sources, CAFOs, farming activities, agricultural industrial processing, and natural environmental allergens. In 1999, a total of 1,566 Iowa children, under age 18, were hospitalized because of asthma.[28]

Table 4: Iowa Schools Near Coal Plants

Schools and coal plants tracked by shared municipality

Number Schools Near Coal Plants	502
Children in these schools	172,213
Total # Iowa Students	526,766
% Iowa Students Attending School Proximal to Coal Plants	**32.69%**

Source: Iowa Department of Education enrollment statistics for the most recent school year (2009-2010) in both private & public schools, preK through 12th grade (http://www.iowa.gov/educate/index.php?option=com_docman&task=cat_view&gid=512&Itemid=55)

But children can be exposed to environmental pollutants far earlier: in the womb and at the breast as well as during play. Several investigators have noted an association between exposure to increased levels of air pollutants during pregnancy and during the first year of life with increased incidence of infant mortality including sudden infant death syndrome (SIDS) in the very early months (1-3 months of age). In particular several authors note that elevated levels of PM, SO_2 and NO_2, among other pollutants, may be important risk factors for SIDS.[29]

Emerging science links cognitive deficits including autism and structural brain abnormalities with air pollution[30] and mercury exposure *in utero* or in infancy. There is strong evidence for fetal neurotoxicity causing neurologic and developmental abnormalities with exposure to methylmercury, lead and other heavy metals even at low concentrations. In fact, exposures at any level have measurable effects. A lower level below which some effect does not occur has not been established.

In a pregnant woman's body mercury passes to the fetus and may accumulate there. Mercury levels in a fetus's umbilical cord blood can be 70% higher than those circulating in the woman's blood. In this way, a mother with no symptoms may give birth to an affected infant. Mercury in mothers' blood and breast milk too can interfere with the development of babies' brains and neurological systems leading to learning disabilities, attention deficit disorder, problems with coordination, and lowered IQ , which in the worst cases, can mean frank mental retardation.

New York City's Mount Sinai School of Medicine researchers published results in 2005 using data from the U.S. Centers for Disease Control and Prevention and elsewhere linking elevated mercury levels with IQ loss. They estimated that 300,000-600,000 children each year are born with levels of mercury in their blood associated with a loss of IQ which results in costing the child, family and society up to $2.2 - 43.8 billion.[31] [32] The researchers further suggested mercury from coal fired power plants is associated with 231 cases (range 28-2109) of frank mental retardation annually costing an additional $2 billion each year. Their risk analysis demonstrated installation of stack filters at the coal plants is associated with less cost overall. Of course, capturing what now goes up the stacks and into the air means more mercury is deposited in unregulated coal ash impoundments.

Elders and those with chronic diseases

Iowa has a far greater percentage of elders than many states with about 14.9 percent over age 65 versus about 12.4 percent for the US overall.[33] This percentage is increasing due to several factors including out migration of the younger population and a low birth rate. Of all 50 states, Iowa ranks 2nd after Florida as having the greatest percentage of the population over age 85. The vast majority of Iowa's elders, including the oldest old remain independently dwelling. However many live with chronic diseases, have significant functional and economic limitations, and have increased susceptibility to the adverse effects of poor air quality. Over a quarter of all Iowa elders reside in Polk, Linn, Scott, and Black Hawk counties. In some rural Iowa counties, elders can make up more than half of the resident population.[34]

Ever since the seminal work done on particulate air pollution and mortality in the 1990s scientists have realized that across the States, thousands of elders and people with chronic disease die prematurely each year from exposure to fine particulate matter.[35] Elderly persons with chronic obstructive pulmonary disease (COPD) or coronary heart disease are most susceptible to the adverse effects of $PM_{2.5}$ that include increased mortality, increased respiratory irritation, asthma, use of asthma medications, and hospitalizations for their effects. Asthma mortality is increasing among those greater than 85 years of age.[36]

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Agricultural Interactions with Coal Risks

"In Iowa, most fine particle pollution forms in the atmosphere when ammonia (from animal feeding operations, fertilizer application and other natural sources) combines with sulfuric or nitric acid (from power plants, automobiles and other combustion sources) to create tiny particles. Smoke also sends fine particles directly into the air. "

— Richard Leopold[1]

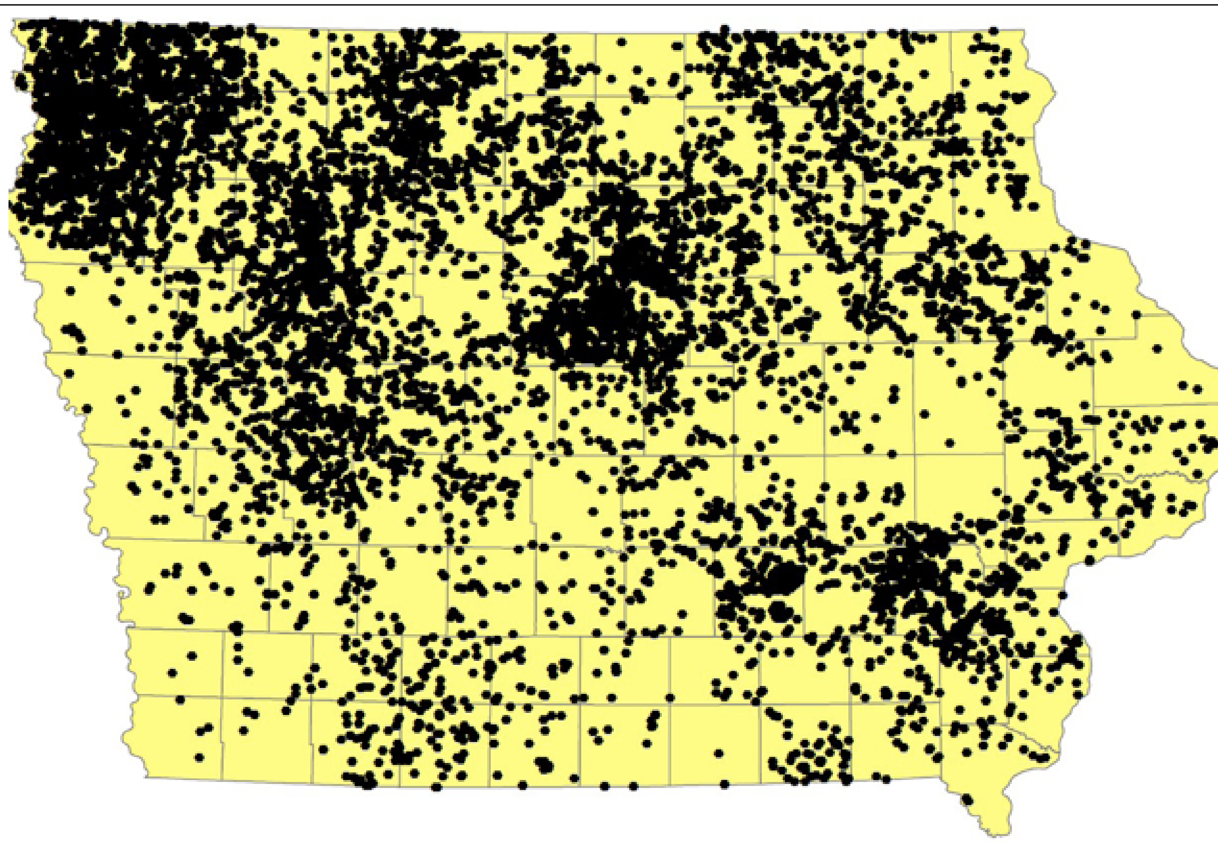
Iowans are not exposed to nor affected by the emissions of coal plants alone. The growth in coal fired energy in Iowa is coincident with the production and use of other industrial and agricultural chemicals known to release many of the same chemicals of concern as well as chemicals that interact with those being released by the coal plants. The presence of such interactions and others were considered when conducting the mapping project because of the ubiquity of industrial agriculture across Iowa, its contributions to, interactions with, and modifications of the state's air quality.

CAFOs and Methane/Nitrogen

Iowans are exposed to relatively high levels of coal combustion products on a per capita basis, but the composition of their airsheds includes exposure to high levels of the atmospherically important emissions from confined animal feeding operations. These industrial scale feeding operations for production of hogsand chickens, in particular, are prevalent across Iowa. (See Map 8: Iowa CAFOs.)

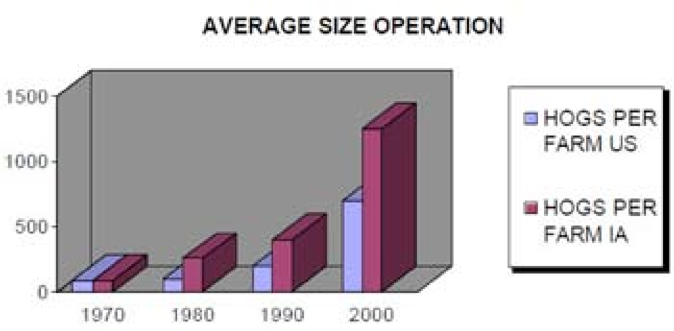
The confined animal feeding operations (CAFOs) have become quite concentrated in Iowa which leads the nation in hog production and egg laying. The average size of the hog operations has increased greatly over recent decades as have turkey and chicken egg production industries. In fact, Iowa is now number one in the US in egg layer numbers. emissions from both operations are increasingly concentrated in Iowa air. (*See Figure 7: Average Hog Farm Size*.)

Map 8: Iowa's CAFOs
Data from DNR



Source: this map on the Iowacoalhealth wiki site was created using ArcView in GIS from the raw GIS data from the Iowa DNR Geographic Information Systems Library hosted at the University of Iowa site: http://www.igsb.uiowa.edu/nrgislibx/ Data last updated 2/19/10 of registered CAFOs in Iowa

Figure 7: Average Hog Farm Size



Source: Iowa Concentrated Animal Feeding Operation Air Quality Study
Chap 2 Industry Structure & Trends in Iowa, p. 24.
http://www.public-health.uiowa.edu/ehsrc/CAFOstudy/CAFO_finalChap_2.pdf

All these facilities release a great deal of directly irritating and atmospherically important greenhouse gases like ammonia and methane and large quantities of waste which also contribute to the pollution of Iowa's watersheds. Iowa raises an average of 11.3 hogs for every citizen in its population. In 2008 Iowa's 5,000 confinement hog facilities, home to almost 20 million hogs[2], generated over 50 million tons of raw manure, or 16.7 tons for every Iowan. Not to be overlooked, as we've seen in recent years, CAFO production areas are also prone to cyclical flooding.

Whether considering the surface impoundment of coal ash or animal manure, the risks to the environment are similar and additive.

As Professor Thorne and others note,

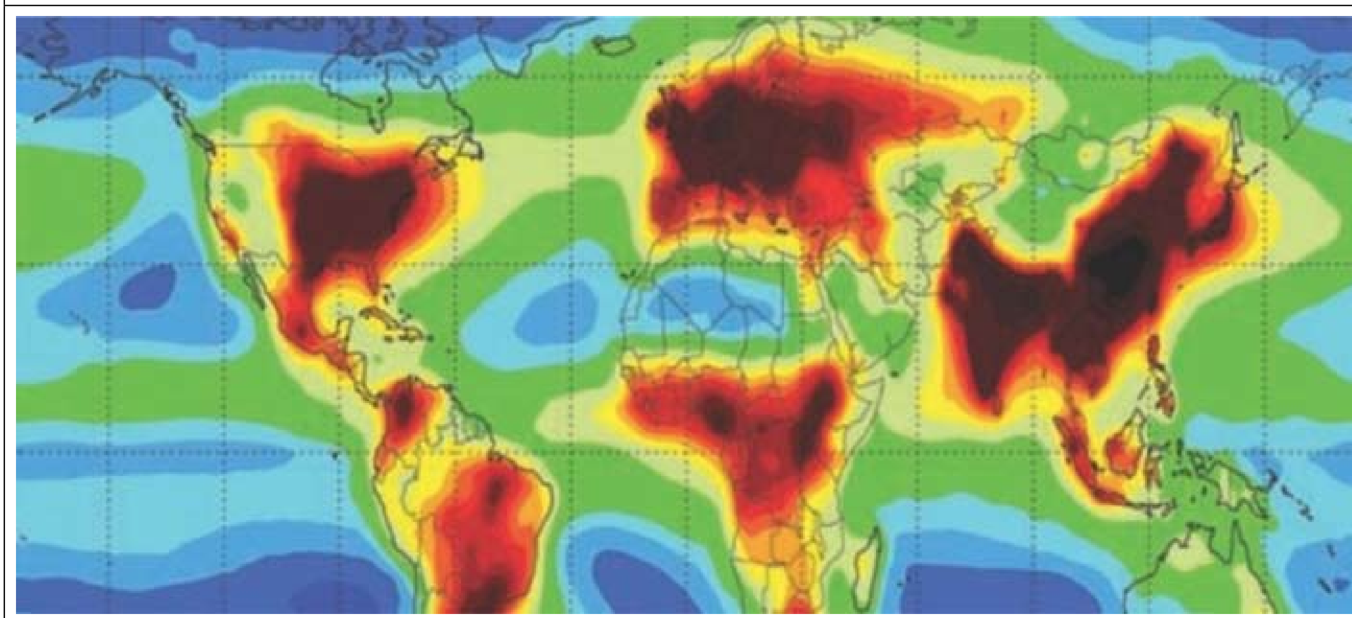
> Air quality data for CAFOs are quite limited. There are relatively few monitoring programs for large scale livestock production compared to other industries that are regulated. This is further complicated by the fact that the air emissions from CAFOs include a wide array of toxicants including gases, vapors, odoriferous compounds, particulates, and bioaerosols. There are no federally mandated monitoring programs in the United States and only a small number of states have instituted their own monitoring.[3]

Researchers with the Iowa Department of Public Health found there was a high prevalence of asthma among children living on farms that raise swine (44.1%, $p = 0.01$) and that raise swine and add antibiotics to feed (55%, $p = 0.013$).[4] -

Reactive Nitrogen

There are yet other closely related important considerations for Iowa's industrial agriculture. Iowa is the largest corn producing state in the US but ranks 10th in lands in farming and 3rd for the market value of its agricultural sector[5]. Reactive nitrogen species from the intensive use of nitrogen fertilizers on Iowa's vast corn fields is another

Map 9: Reactive Nitrogen Hot Spots



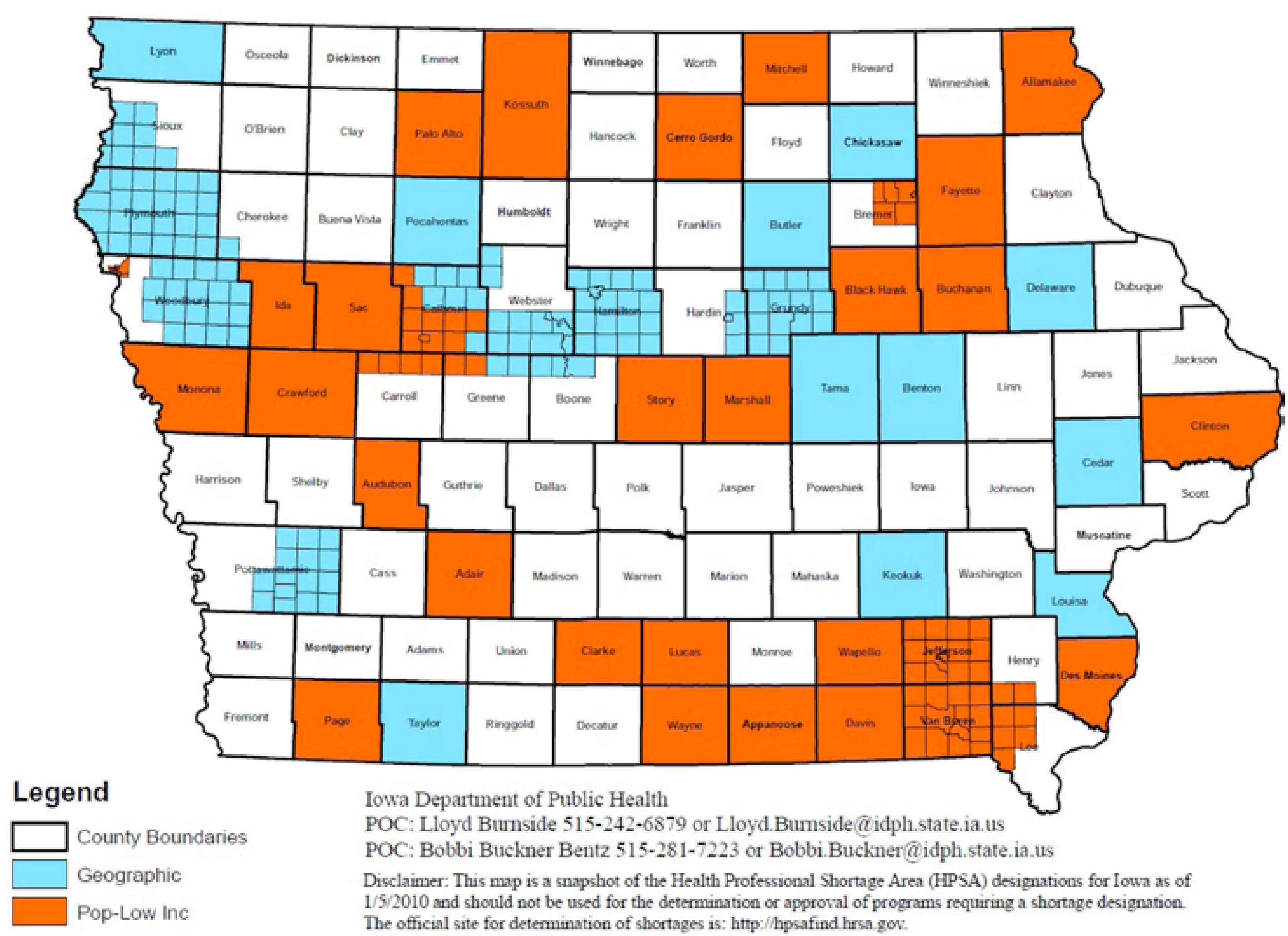
Source: http://www.wired.com/wiredscience/2008/05/reactive-nitrog/

important factor that degrades Iowa's air quality. (*See Map 9: Reactive Nitrogen Hot Spots.*)

Reactive nitrogen molecules are analogous to free oxygen radicals: an altered electron configuration makes them especially unstable, and more likely to wreak health and environmentally related havoc. These molecules are particularly active in the presence of sunlight and volatile organic compounds to form smog or ground level ozone. Like the emissions from coal plants reactive nitrogen acts to damage lung tissue, reduce lung function, exacerbate asthma and heart disease, and can cause premature death for children and outdoor workers. Furthermore, nitrous oxide (N_20) is 300 times more potent than CO_2 as a greenhouse gas. In drinking water N_20 leads to the risk of blue-baby syndrome[6].

Reactive nitrogen levels in the U.S. doubled between 1961 and 1997, and continues to increase due to human activity. The largest increase was in the use of nitrogen fertilizer, even as air emissions from the combustion of fossil fuels also increased significantly–beginning in the middle of the 19th century. The production and use of nitrogen based fertilizers has increased most dramatically in the last several decades. As an agricultural state Iowans cannot underestimate the role of agricultural activity in the release of reactive nitrogen and its contribution to negative health effects. To reduce the health impacts of this chemical, fossil fuels and farming practices have to be addressed simultaneously.

Map 10: Federal Primary Health Care Shortage Designations–January 2010



Source: http://www.idph.state.ia.us/hpcdp/common/pdf/health_care_access/federal_hpsa_map.pdf

Rurality

> "There is scarcely any writer who has not celebrated the happiness of rural privacy, and delighted himself and his reader with the melody of birds, the whisper of groves, and the murmur of rivulets"
>
> — Samuel Johnson

Finally, there exist a number of reasons why rurality itself challenges Iowans unwittingly exposed to the interacting air pollutants of coal and agriculture. The dispersed, aging population, coupled with rural Iowans' dominant value of tough self-reliance can be an important yet under-appreciated obstacle to linking and interpreting exposures and health outcomes. The prevalent social myth equating ruralness with the bucolic, peaceful, pristine and healthy, clouds society's perception of the real and extensive modern damages and dangers associated with the rapidly changing rural environment.

At a most concrete level, rural Iowa has a large number of important medically underserved areas that themselves affect framing and responses to health concerns at the personal and community level. (*See Map 10: Iowa Health Care Shortage Areas.*) This unmet need is not unique to rural areas as evidenced by the over 25 Free Clinics across the state[7], but rurality brings even more acute challenges in life threatening medical emergencies. The best outcomes, in the case of severe asthma attacks, heart attacks, and strokes, require rapid recognition, response, and appropriate emergency medical treatment.

Geographical challenges of rurality delays access to advanced medical care centers which likely contributes to excess morbidity and mortality for some medical emergencies. Additionally, given Iowa's vast rural areas, air quality monitors for PM, NOx, or NH_3 are not available in the areas where there is likely to be interaction between coal, corn, and CAFO associated air pollution especially in the central and northwestern counties of the state. Thus, air quality alerts can not be provided in timely fashion.

Early cardiovascular, metabolic, or oncologic disease manifestations can be subtle. Health literacy for many rural Iowans is likely to be low[8]. Additionally, there is poor dissemination of information about the health risks associated with exposure to environmental pollutants in the air and water. This is not a problem specific to Iowans, but it can exacerbate the health risks of rural living. In such settings, the complexity of causal factors along with inattention to or recognition of them, all play a role in rural resident's acceptance of the status quo, avoidance of attribution, and possibly postponement of needed care.

Endnotes

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5. U.S. Energy Information Administration Independent Statistics and Analysis. Iowa. Quick Facts and Overview. Accessed 6/27/10 at http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=IA.
6. Fact Sheet: Reactive Nitrogen. 2009. http://www.initrogen.org/fileadmin/user_upload/Reactive_nitrogen_fact_sheet.pdf.
7. For a description and listing of all these varied clinics visit. Accessed 7/25/10 at http://www.freeclinicsofiowa.org/criteria.shtml. As further evidence of efforts to fill Iowa's health services gaps, Iowa also has a number of federally funded Community Health Centers designed to work with and serve low income citizens.
8. See IDPH program Plain and Simple. Lack of Health Literacy fairly common across the nation. Accessed 7/25/10 at http://www.idph.state.ia.us/health_literacy/.

Methodology

> "Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house."
>
> — Henri Poincaré

Government and peer reviewed sources that assess health impacts of coal emissions and coal combustion waste products were paired with Iowa demographic and health data. Additional background materials, literature, and sources - can be found on the web site, www.coaliniowa.org.

Mapping and Estimating Coal's Costs on Iowa's Health

While the national EPA and Energy Information Administration offices compile regional data, there are important local variations that could only be captured at the local level. With help from the staff of the Iowa Division of Natural Resources, the Iowa Department of Public health, and other public offices tasked with the management of industrial licensing and monitoring, this study tracked and mapped the location and capacity of coal burners across the state. Detailed open source data used in this study on all the coal plants in Iowa is available at www.coaliniowa.org. Additionally, data on CAFOs and on air quality monitoring in Iowa was collected. Health outcomes selected to be mapped were determined by what is known about specific diseases as reviewed and the available age-adjusted, standardized and anonymous health data from the Iowa Department of Public Health[1].

While the national EPA and Energy Information Administration offices keep much of this data, there are important local variations that could only be captured at the local level. The review and mapping were followed by an exploration and mapping of a selection of disease states experienced across Iowa as reviewed above. Health outcomes selected to be mapped were determined by what is known about specific diseases as reviewed and the available age-adjusted, standardized and anonymous health data from the Iowa Department of Public Health.1 Air quality monitoring data from across the state were also examined.

Numerous sources and databases from federal, state, business, and respected non-governmental organizations were consulted to compose spreadsheets and maps comparing pollution sources and health outcomes of interest. Definitions, dates, geographic marker systems, inclusion or exclusion criteria, and comprehensiveness of the data were not uniform among the resources. Some sources list only electricity generation plants with a generating capacity of 100 megawatts. Coal is burned for different purposes in a variety of plants, utility electricity generation, manufacturing, agri processing, or miscellaneous. Some plants consider the amount of coal burned to be proprietary information. A single plant or facility can have any number of boilers, some of which do or do not burn coal, some of which only operate during periods of peak demand; other plants or coal boilers are designed for co-generation and utilize more than one fuel source depending on yet other factors. The EPA lists sites based on CO_2 emissions, others list plants by production of PM, NO_x or SO_x. Similarly, depending on the source, data could be organized by capacity, power output, actual, emissions, or efficiency and thus offering varying challenges in matching pollution inputs to estimating health risks and outcomes.[a]

Emissions data were obtained from the Iowa DNR Air Quality Bureau's records. Iowa DNR data on emissions as noted above, originates from self reported forms. All coal fired facilities subject to Title V of the Clean Air Act must supply the DNR with an annual estimate of their airborne emissions of certain toxic compounds. Facilities are also to indicate in what season the coal is burned. Self reports are due in the Spring of the following year; records from 2008 are now becoming available in 2010. At the time of this study, emissions inventories for 69 boilers from only 27 facilities (out of 36) were available for 2008. They were used to determine how much coal was consumed by which boiler at which plant and estimate how much PM, NO_x, and SO_2 was released.

To estimate health effects, data on hospital inpatient discharges for the period from 2004 to 2006 (the most recent available) was obtained from the Iowa Department of Public Health. Quantities of emissions, locations of coal plants and known CCW disposal sites, and disease rates were subsequently mapped using ArcGIS version 9.3.

Reconciling and weighing these many factors and variables make the compatibility, interpretation, and intersections of these disparate data sets challenging. It is important to realize that most monitoring and record keeping is not done with the goal of ecological and epidemiological analysis in mind but to meet reporting and record keeping requirements that are not standardized across industry types and/or agencies.

[a] For detailed information or descriptions of these various factors, refer to relevant Excel spreadsheets and maps available at: www.coaliniowa.org/

Bearing these points in mind, the maps were designed with the basic understanding that emissions from coal fired facilities disperse widely and variably. Yet, their diffusion and greatest impact is largely over defined geographic space (see for instance the diffusion of a proposed plant presented in Stigliani2). Analysis can link these emissions across space with the incidence of specified health outcomes across the same space.

GIS software statistically determines clustering/dispersal of similar phenomenon in a process called spatial autocorrelation done at two levels, in two similar but different ways.

The first is the Moran process:

1. Calculating the Global Moran Statistic helps determine if throughout a data set there is a clustering of like values. For example, do nearby counties have similar rates of diabetes? Or stroke? This produces a statistic, not a map.

2. The Local Moran Statistic which measures, by county, the similarity of rates to nearby counties allows the determination of clusters and outliers. This produces a map of those clusters and outliers for each county, and an associated p-value.

The second is the Getis-Ord process:

1. The Getis-Ord General G calculation is used to determine whether the high rates cluster or the low rates cluster. The result is a score ranging from -1 to 1 (1 meaning high rates cluster strongly, -1 meaning low rates cluster, 0 meaning random dispersion) and a Z-score indicating strength of significance.

2. The Getis-Ord General Gi calculation determines where the "hot spots/cold spots" occur. The calculation examines each feature (in this case, county disease rates) in comparison with its neighbors (the impact of which was defined in this case as inversely distant - the further away from the feature in question, the less impact other features had.) To achieve significance, the sum of the rates for a county and its neighbors is compared relative to the sum of all counties. If the county's rate is too different from the expected rate to be random, the rate is said to be statistically significant. The degree to which it is significant is determined by the Z-score. In this context a map is produced with a Z-score for each county, and an associated p-value.[3]

For each of seven hospital discharge diagnoses (asthma, COPD, acute respiratory infections, respiratory cancers, diabetes, coronary heart disease, and stroke) clustering of counties with respect to high or low diagnosis incidence was determined. The degree to which each county might represent a "hot" or "cold" spot was measured by a Z-score. For each county, the significant ($p < 0.05$) Z-scores were summed and then mapped in order to demonstrate the degree to which each county was a hot or cold spot. While a county could be a hot spot for one disease and a cold spot for another, cancelling out the Z-scores when summed, this occurred in only two or three counties.

Proximity Analysis: Role of Race and Poverty in Iowa

To investigate whether minority and impoverished Iowans are more likely to live closer to or in the path of the emissions and waste products generated by the coal plants, census data estimating population make up in proximity to the plants was examined. The census tract number corresponding to the location of each coal plant was obtained by entering its latitude and longitude coordinates into the U.S. Census Bureau's American Fact Finder tool. Data on median income and race from the 2000 census was obtained for each census tract and county containing a coal-fired facility, as well as the entire state. The categories of race examined were "Black or African-American only" and "Hispanic or Latino" as these are the significant minority populations in Iowa. Tract-level median income was compared to county-level income. County-level statistics were also compared to state income statistics to determine if coal plants happen to be sited in counties with lower incomes or counties with above average percentages of minorities.4

Estimated Health Costs–Using The COBRA Tool

The Co-Benefits Risk Assessment (COBRA) Screening Model is produced by the Environmental Protection Agency in association with Abt Associates--a research and consulting firm with expertise in social, economic and health policy.[5] The COBRA screening model is a standalone Microsoft Windows application that enables policy analysts to quickly obtain a first-order approximation of the costs and benefits of different emission scenarios and to compare outcomes in terms of changes in ambient particulate matter (PM) concentrations, related health effects, and monetary impacts.[6]

COBRA serves as a preliminary screening tool to identify those scenarios that might benefit from further evaluation with more sophisticated air quality modeling approaches. Using the COBRA tool, data found in this study was evaluated according to scenarios that answer this question: What would be the impact on human health if the percentage of electricity generated in Iowa from burning coal were reduced to align with the national average? The most recent EIA data indicates that 72% of Iowa's Net Electricity Generation is from coal-fired power plants. For the same period, 46.5% of the United States Net Electricity Generation is from coal-fired power plants. This scenario was tested by the COBRA tool to estimate how Iowa health outcomes and costs incurred would change if only 46.5% of Iowa's electricity was generated by coal.

Potential Confounders considered

When conducting the mapping project and considering the COBRA analysis, the presence of several potential confounders were considered.

Air Pollution from Non-point Source Fossil Fuel Emissions

Atmospheric NO_X and PM are both also considered to be markers of traffic-related air pollution as well as components of coal emissions. Many air quality studies measure the health effects of these factors in urban populations near high traffic areas. Iowa's greatest transportation related sources of air pollution run along I-80; however, there was no particular increase in disease patterns noted along I-80. Similarly, tractors and other large industrial agricultural machinery dependent on fossil fuel, including diesel and gasoline, are all sources of combustion air pollutants similar to those of coal though more variable over the course of the year. Though seasonal, rural production of these pollutants by agricultural machinery is likely to be relatively geographically uniform across the state.

Indoor Air Pollution

Indoor air pollution originates from several sources. The variety of indoor pollutants from outgassing, wood stoves, cooking, smoking, animal dander, mold, and other chemical products used within the home can be expected to vary significantly from house to house in any neighborhood. Of potential sources of indoor air pollution only radon may have a discernable pattern and is described elsewhere. The presence of these pollutants has more to say about the health of specific individuals than anything they encounter systematically outside the house, and we can expect their effects to be essentially random.

Smoking

Respiratory cancers are the result of behaviors or exposures combined and experienced over time beginning 20 years ago or more. Like the rest of the nation, smoking among Iowans has steadily declined over recent decades. According to the CDC tracking system, in 2000, 23.3% of Iowans smoked, but by 2008, after various intervention efforts, including the increase in tobacco taxes, the percentage of Iowa smokers had dropped to18.8% overall.[8] The Iowa Department of public health lists this latter figure as only 14%. Iowa can expect to continue to see respiratory cancers as a result of smoking history and/or long term exposure to radon. As of 2005 smoking still appeared to be more prevalent in census tracts with lower median household income, higher percent of African American residents, and higher percent of Latinos.[9] However, as mentioned for the proximity study, pairing these issues was difficult to accomplish within the bounds of our study. Thus the authors acknowledge that smoking may continue to be a risk factor to explain some of the rates of heart attacks, COPD or asthma in some populations of Iowans–but increasingly less so especially in areas where rates of smoking are dropping but rates of heart disease or respiratory disease are increasing.[10]

Iowa Superfund Sites

In response to the Love Canal disaster in New York in 1980 the US Congress enacted CERCLA, the Comprehensive Environmental Response Compensation and Liability Act and created the Superfund which is a taxing structure created as part of CERCLA. Superfund taxes hazardous waste disposal in the U.S. to create a fund of money to remediate the worst of the worst sites in the US. The law provided authority to the federal government to respond to releases or threatened releases of hazardous substances. Such substances are usually, but not exclusively industrial solid and liquid waste, and some municipal waste, usually landfills. Iowa is home to 11 priority designated Superfund sites with a 12th Waterloo site, in the category "study underway."[11] Concern at most Iowa sites involves contamination or threats of contamination to surface or drinking water, or local wildlife; none is associated with air quality. While the concern is not necessarily over aerosolized contaminants, it is of concern if contaminants, especially the heavy metals from coal combustion wastes add to or exacerbate those already found in, or threatening, the watersheds of the identified superfund sites. Four of the Superfund sites stem from earlier coal gasification plants reminding us of the indestructible and persistent nature of waste products derived from coal.

Endnotes

1. Initially we had considered using Healthcare Cost and Utilization Project (HCUP) a multi-state, all payer, encounter-level, health care data base that provides a census of hospital care, not a sample– from acute care, academic and community hospitals. Then we found it had many of the same problems as the Iowa Department of Public Health data. It does not cover clinic or office outpatient visits, and cannot reliably identify people who go out of state for care.
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4. 2008 County Population Estimates and 2000 U.S. Census American Fact Finder. Accessed 7/26/10 at http://www.census.gov/popest/counties/CO-EST2008-01.html. Accessed 7/26/10 at http://factfinder.census.gov/home/saff/main.html?_lang=en.
5. To learn more about Abt Associates and their projects and staff. Accessed 7/26/10 at http://www.abtassociates.com/.
6. COBRA is designed to allow users to easily analyze the health effects of changes in emissions of PM, as well as pollutants associated with the secondary formation of PM (sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds), at the county, state, regional, or national level. COBRA presents these estimated county-level health impacts in both tables and maps. Accessed 7/26/10 at http://www.epa.gov/statelocalclimate/resources/cobra.html.
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11. Several EPA and related sites describe current and former Iowa National Priority Superfund sites. For descriptions and current status of each see several resources: All accessed 7/26/10 at http://www.epa.gov/superfund/sites/query/queryhtm/nplfin.htm#MN, http://www.epa.gov/region07/cleanup/npl_files/index.htm#Iowa, and http://www.scorecard.org/env-releases/land/rank-sites.tcl?fips_state_code=19

Results

"To talk about whether pollution has increased or decreased, one must decide what one means by it and where to look for it."

— Peter Thorsheim[1]

Iowa hospital discharges for 2004-2006 by county are shown in Map 11.

The authors learned that the Iowa Department of Health does not have discharge diagnoses for Iowans hospitalized and discharged in other states but has estimates of how often this occurs. Map 12 shows the percentage of hospital discharges for Iowans that were out of state.

To account for out of state discharges, discharges by county were subsequently normalized per 10,000 population, which requires the assumption that there is no significant difference in diagnosis mix between in-state and out-of-state discharges.

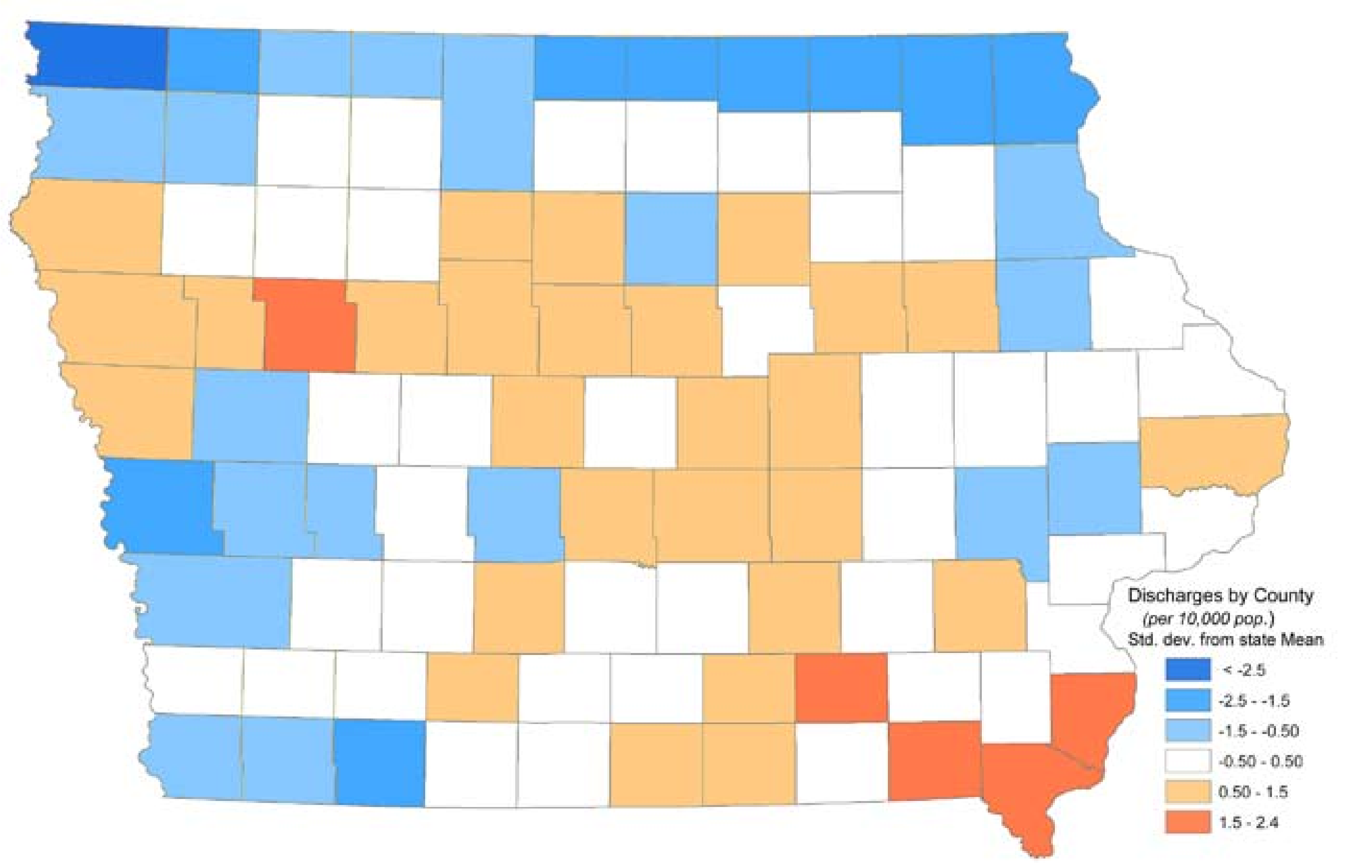
A breakdown of Iowa hospital discharges for 2004-2006 for each of the diagnoses of concern are show in the maps in Appendix I. The Local Moran Statistic calculated for the diagnosis categories of concern indicated that the hospital discharge data set contained significant geographical clustering. (*See Table 5)*

Global spatial cluster analysis of hospital discharge data using the Global Moran I test for clustering of similar values revealed evidence for clustering among counties in the Iowa health data for most of the seven individual target diseases and for all seven diseases lumped together. The evidence for the presence of clustering in the hospital discharge data was strong for each of the individual target diseases, stroke, coronary artery disease, asthma, COPD, and acute respiratory infections. Evidence for clustering was present for diabetes but was weaker. There was no evidence for clustering in respiratory cancers. Concordance between Stroke and CIHD is not surprising as both often share a common progressive vascular pathology.

These results justified further local analysis for hot/cold spots in the hospital discharge data. Local spatial cluster analysis of hospital discharge data was then done using the Getis-Ord General Gi test for clustering of high and low

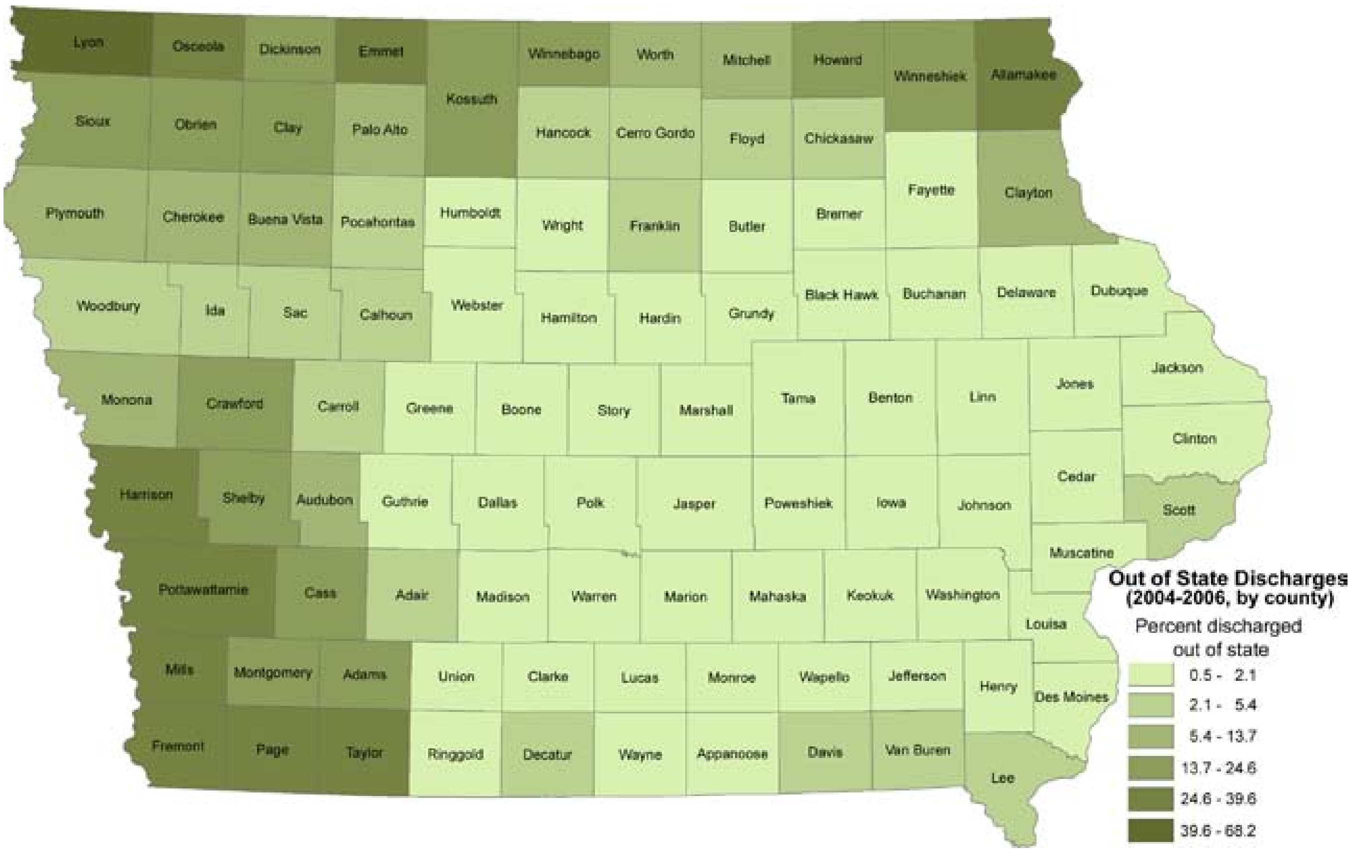
Map 11: Per Capita Discharges for Iowa Counties for all diagnoses, 2004-2006
(Data expressed as number of standard deviations above or below the state per capita mean.)

Counties with a positive number of standard deviations have a higher per capital hospitalization rate. Counties with a negative number of standard deviations have lower per capita hospitalization rates.



Map 12: Out of State Discharges for Iowa Residents, 2004-2006
(Data from the Iowa Department of Public Health expressed as percentage of total county discharges.)

Diagnoses associated with these discharges are not known. These discharges were not included in Iowa totals. Total discharges for all diagnoses, by county, were subsequently normalized across counties by expressing totals per 10,000 population, which requires the assumption that there is no significant difference in diagnosis mix between in-state and out-of-state discharges.



values. Statistically significant hot and cold spot counties were identified for diabetes, stroke, coronary artery disease, COPD, and acute respiratory infections. Though hot spot counties were identified for asthma statistical significance was not found.

Two maps were created that bring much of coal plant and health data together. First, *Map 13: $PM_{2.5}$ Emissions Relative to Coal Input for Iowa Coal Facilities* graphically demonstrates several facts about 25 of Iowa's coal plants—those for which estimated data on $PM_{2.5}$ emissions is available.

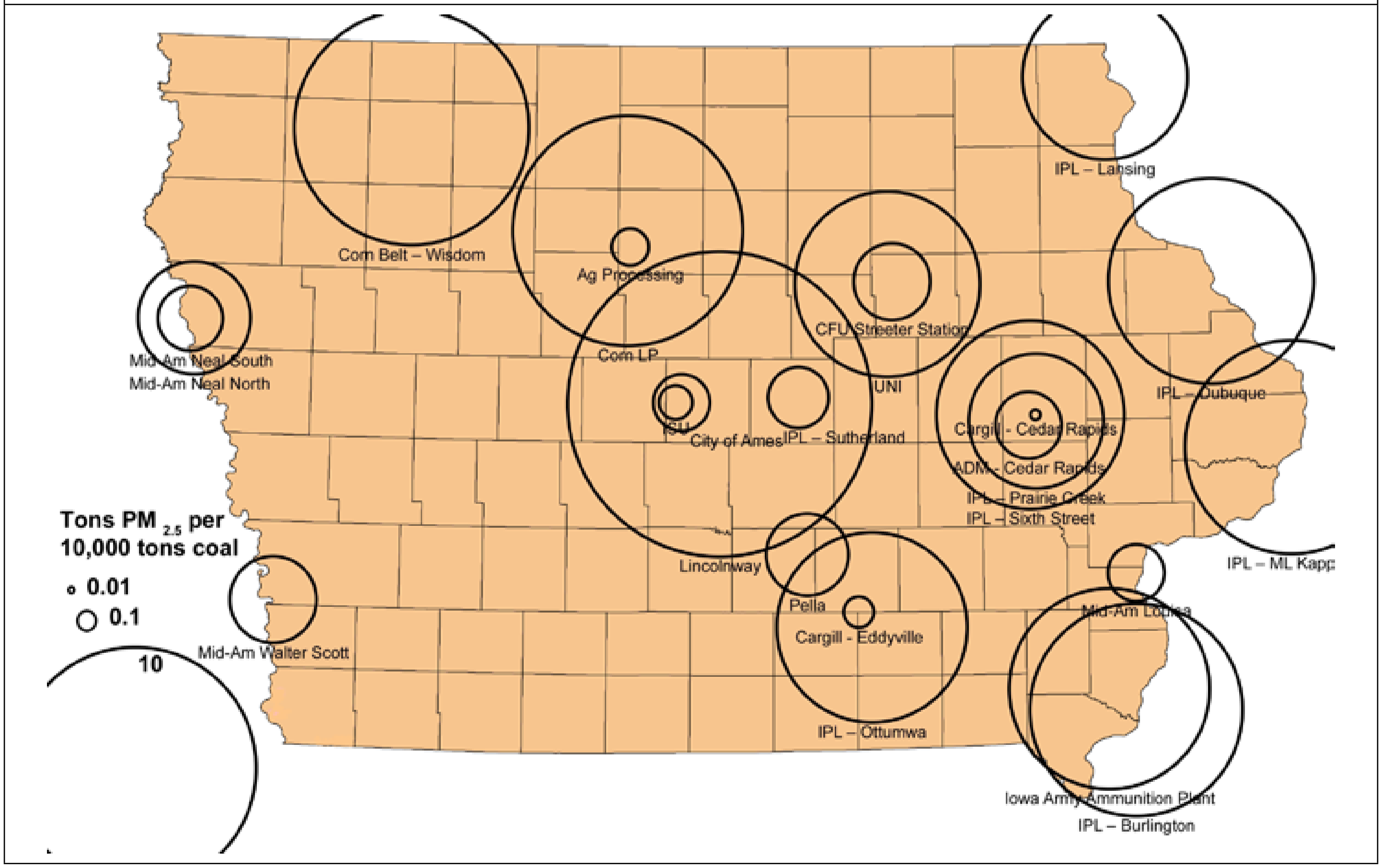
Table 5: Global Spatial Analysis

Diagnosis	**Global Morans I** *(Clustering of similar values)*		**Getis-Ord General Gi** *(Clustering of high and low values)*	
	Z-score	Probability	Z-score	Probability
Diabetes	1.72	.05-.1	2.55	< .05
Stroke	6.05	< .01	4.61	< .01
CIHD	6.98	< .01	5.64	< .01
Asthma	3.25	< .01	1.15	random
COPD	4.09	< .01	2.42	< .01
Respiratory Infections	4.01	< .01	2.17	< .05
Respiratory Cancer	1.43	random	1.36	random
All	4.57	< .01	3.63	< .01

Map 13: $PM_{2.5}$ Emissions Relative to Coal Input for Iowa Coal Facilities

(Circle diameter indicates the $PM_{2.5}$ emissions from each plant in terms of tons of $PM_{2.5}$ released per 10,000 tons of coal burned.)

The larger the circle, the more inefficient a plant is in containing $PM_{2.5}$, i.e., dirtier with respect to $PM_{2.5}$. These circles do not represent the total $PM_{2.5}$ emissions for each facility.



The circles indicate the location of coal plants. The relative sizes of their circles is not an indication of their emission plumes but rather an indication of the tons of $PM_{2.5}$ released to the environment relative to tons of coal burned in the plant, creating a kind of "inefficiency" indicator. The map also demonstrates the relative crowding of the plants in the Eastern third of the state and indicates that many of the plants considered "$PM_{2.5}$ inefficient" are in eastern Iowa, exactly where there is concern about meeting NAAQS.

Second, because of Iowa's relatively small population and numerous small hospitals distributed across the state, hospitalization data was combined for the diseases of concern (stroke, ischemic heart disease, asthma, COPD, pneumonia, and respiratory cancers). When combined, several counties stand out as demonstrating clustering of hospitalizations for the group of diseases of interest. *(See Map 14: Hot Spots.)* The map reveals hot spot clusters of hospital discharge rates for diseases of concern in the southwest and southeast corners and a central area of Iowa.

The Getis-Ord General G Statistic also identified hot and cold spots in Iowa for the each of the individual diseases of concern. The G statistic for Iowa counties for each diagnosis of concern is shown in the maps of Appendix II.

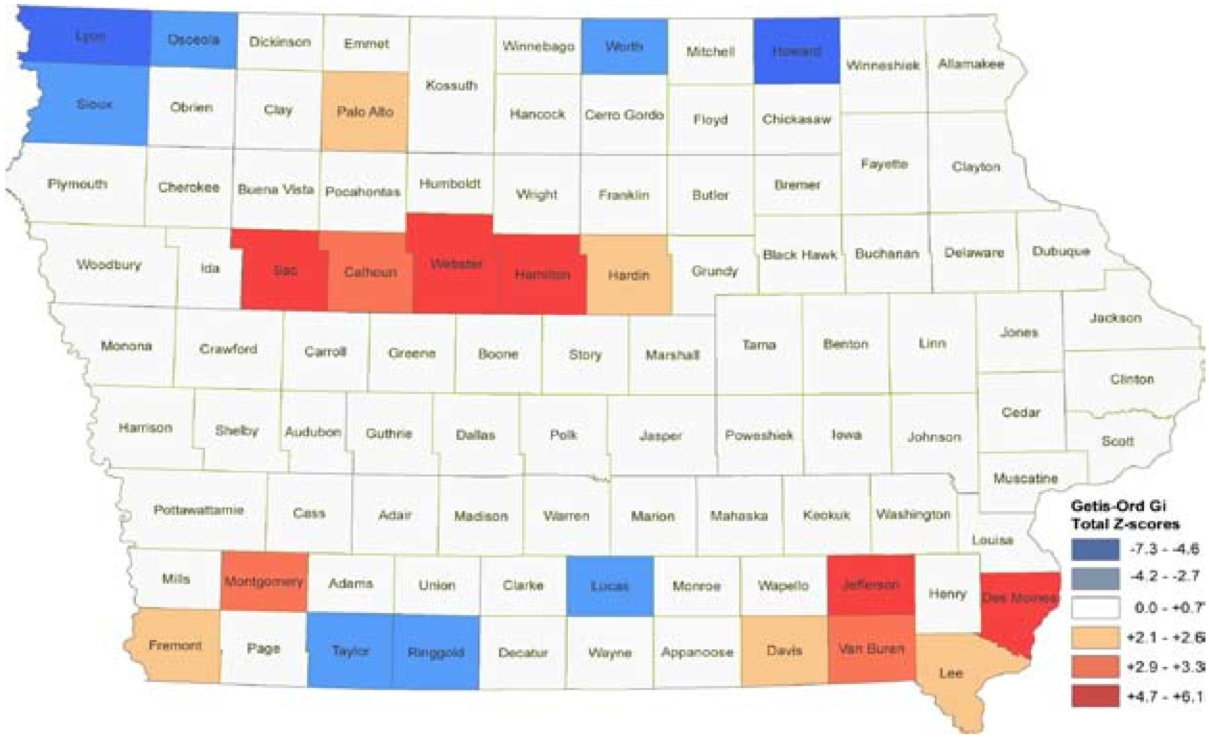
To compare the geographical variation of health outcomes with emissions, two overlay maps were prepared that compare coal plant and CAFO emissions with the hospital discharge rates and with the results of the hot/cold spots analysis.

Map 15 superimposes the $PM_{2.5}$ coal plant emissions and the location of Iowa CAFOs with the hospital discharge rates, by county, for all Iowa hospital discharges. Map 16 overlays the $PM_{2.5}$ coal plant emissions and the location of Iowa CAFOs with results of the hot/cold spots analysis for the six diagnoses combined: asthma, COPD, acute respiratory infections, respiratory cancer, coronary artery disease, and stroke.

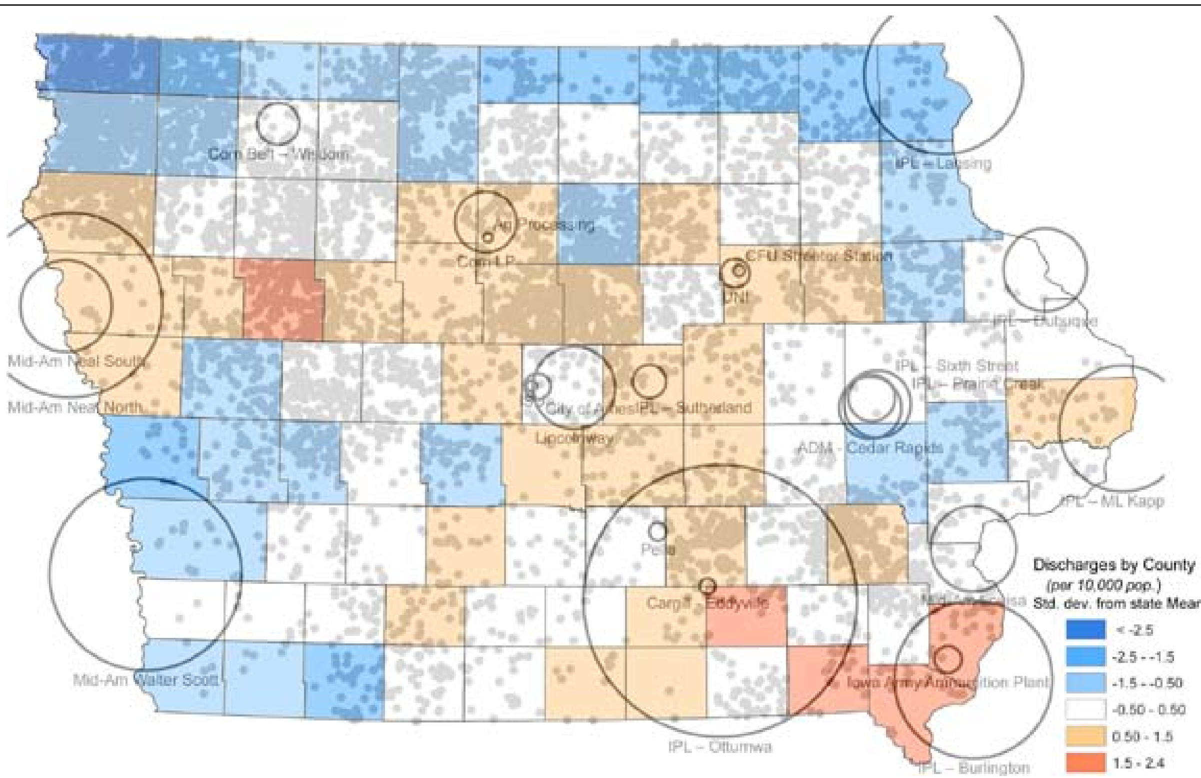
Map 16 shows the total amount of $PM_{2.5}$ emitted for each coal facility and can be contrasted to the depiction of $PM_{2.5}$ emissions relative the total amount of coal burned by the facility in Map 13.

Map 14: Hot Spot Analysis for Combined Iowa Hospital Discharge Rates for Selected Diagnoses
(Map depicts the Getis-Ord Gi Z-score for the six diagnoses: asthma, COPD, acute respiratory infections, respiratory cancer, coronary artery disease, and stroke)

A postive Z-score indicates an area of increased incidence (hot spot), and a negative Z-score indicates an area of low incidence (cold spot).

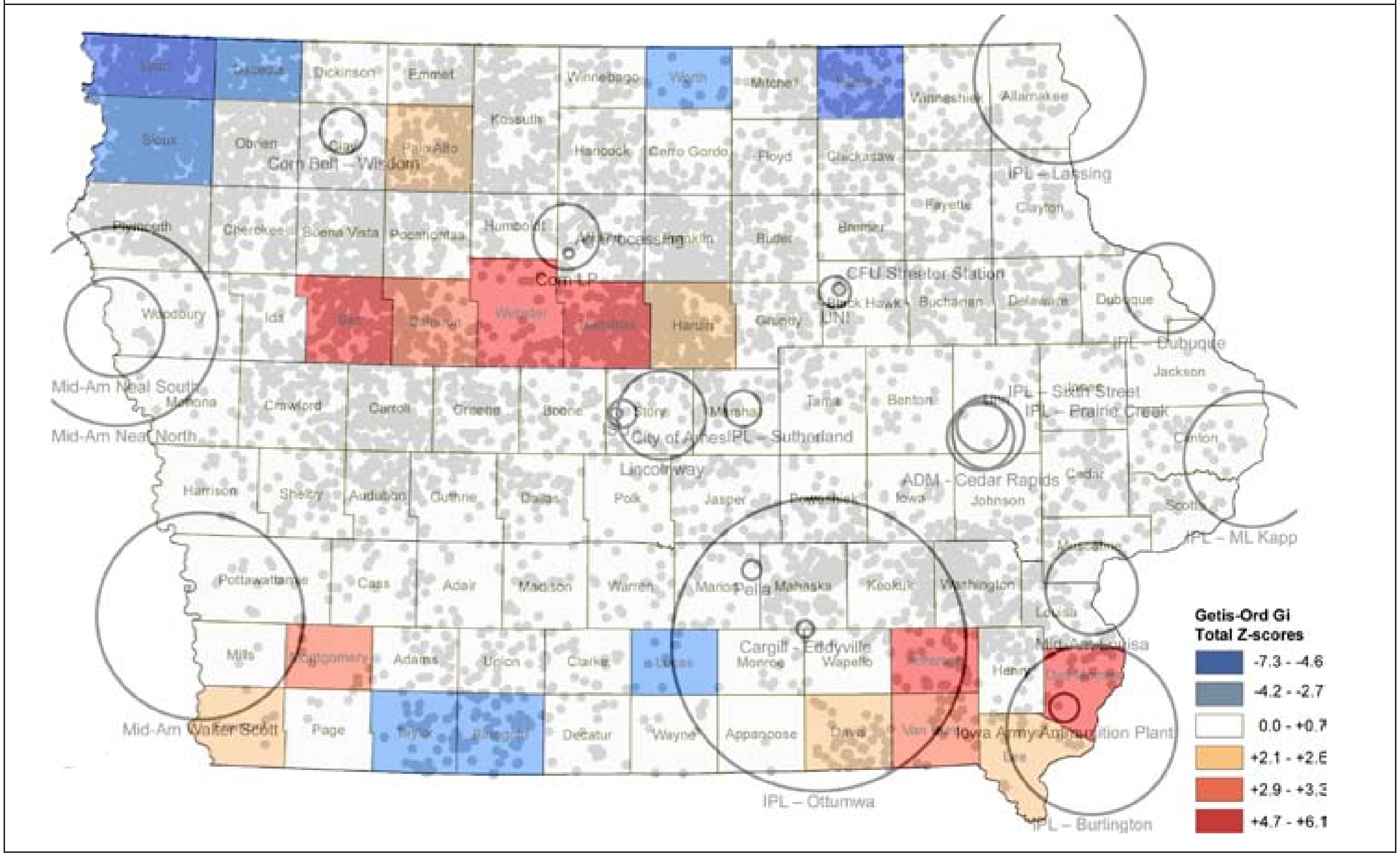


Map 15: Iowa Coal facility PM2.5 total emissions, location of Iowa CAFOs, and per capita hospital discharge rates for all diagnoses, 2004-2006
Key: Circle size indicates total PM2.5 for each coal facility. Grey dots indicate location of CAFOs regardless of size. Colors indicate number of standard deviations, for each county, above or below the state mean, for all Iowa hospital discharges. SO2 and NO$_X$ emission overlays are similar to this PM2.5 overlay



Map 16: Iowa Coal facility $PM_{2.5}$ total emissions, location of Iowa CAFOs, and hot/cold spot cluster analysis for the six diagnoses: asthma, COPD, respiratory infection, respiratory cancer, coronary heart disease, and stroke, 2004-2006

Key: Circle size indicates total $PM_{2.5}$ for each coal facility. Grey dots indicate location of CAFOs regardless of size. Colors indicate the total Gedis-Ord Gi Z-score value. Positive Z-score values indicate diagnosis hot spots. Negative Z-score values indicate diagnosis cold spots. SO_2 and NO_x emission overlays are similar to this $PM_{2.5}$ overlay



Overlay maps similar to Map 16, where SO_2 or NO_x emissions are substituted for $PM_{2.5}$ emissions, have essentially identical appearance. Overlay maps showing with SO_2 and NO_x can be accessed at http://www.coaliniowa.org.

Proximity Analysis: Race and Poverty

One third of Iowa's coal fired plants are located in neighborhoods that are below the median income for counties that, in turn, are below the median income for the state (poorest of the poor neighborhoods), and/or have a high proportion of resident African Americans and Hispanic Iowans. Also, the majority of Iowa's small minority populations are clustered disproportionately in the areas with the most power plants and experience the most days cited for exceeding air quality standards.

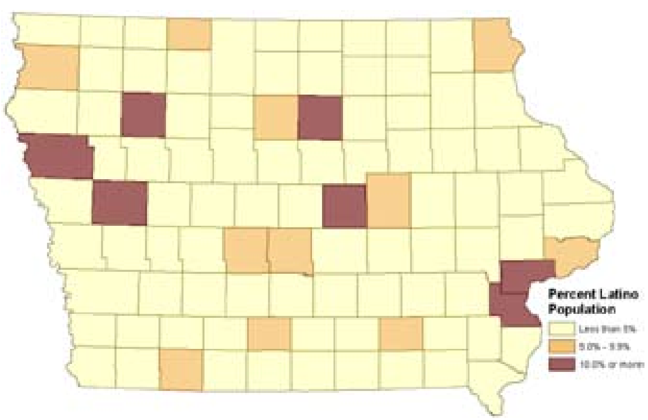
While representing less than 6% of Iowans, 80% of Iowa's African American population cluster in eight cities[2] each one of which is home to at least one coal burning facility. Waterloo, Cedar Rapids, Des Moines, Davenport and Clinton constitute the areas in Iowa with the largest African American neighborhoods. (*See Table 6: African Americans Live Near Coal Plants.*) Similarly, much of Iowa's Hispanic population is located in areas with poor air quality: Muscatine, Des Moines, Sioux City, Council Bluffs. (*See Map 17: Hispanic Population in Iowa.*)

Table 6: Where Do Iowa's African Americans Live?*

Waterloo/Cedar Falls	10,026
Des Moines Metro Area	17,109
Davenport/Bettendorf/Clinton	10,278
Cedar Rapids Metro Area	4,579
Iowa City/Coralville	2,272
Ames	1,323
Burlington	1,332
Sioux City	1,966

*2000 Census reported 60,744 African American Iowans

Map 17: Latinos in Iowa as a percent of total population in Iowa's counties: 2009



Source: http://www.iowadatacenter.org/Publications/hispanic2010

Results of the COBRA Health Costs Model:

A scenario where the percentage of Iowa's electricity generated from coal was reduced from 72% (current level in Iowa) to 47% (the national average) was evaluated using the COBRA tool. According to the COBRA tool estimate, reducing emissions in this scenario would save $71,785,903 in Iowa health costs. Of the total saving 92.1% would be due to a reduction in mortality. As has been asserted in this report, according to the COBRA user's manual,

> "Health researchers have consistently linked air pollution, especially PM, with excess mortality. Although a number of uncertainties remain to be addressed, a substantial body of published scientific literature recognizes a correlation between elevated PM concentrations and increased mortality rates. Both long- and short-term exposures to ambient levels of particulate matter air pollution have been associated with increased risk of premature mortality. It is clearly an important health endpoint because of the size of the mortality risk estimates, the serious nature of the effect itself, and the high monetary value ascribed to avoiding mortality risk."

Reduction in chronic illnesses, chronic bronchitis and non-fatal heart attacks, account for 6.6% of the total savings. The remainder of the savings on health outcomes in this scenario include reductions in infant mortality, respiratory and cardiovascular hospital admissions, acute bronchitis, upper and lower respiratory symptoms, asthma emergency room visits, restricted activity days for children, and lost work days.

The model predicts premature mortality would be reduced by 10 deaths. There would be 7 less cases of chronic bronchitis, 16.8 fewer cases of non-fatal heart attacks with, a reduction by 7 hospitalizations. There would also be a reduction of 310 cases of acute bronchitis, upper and lower respiratory illnesses, and asthma. There would be 1,201 lost work days.

The COBRA tool predicts clear benefits to reducing the percentage of coal based electricity generation in Iowa only enough to match the national average. The primary identifiable improvements in health outcomes would be a reduced mortality rate and reduction of chronic bronchitis and non fatal heart attacks.

Endnotes

1. Peter Thorsheim (2006). Inventing Pollution: Coal, Smoke and Culture in Britain since 1800. Ohio University Press. See also, David Stradling and Peter Thorseim. The Smoke of Great Cities: British and American efforts to control air pollution 1860-1914. Journal of Environmental History. Jan. 1,1999. Available through ProQuest. Accessed 7/18/10 http://findarticles.com/p/articles/mi_qa3854/is_199901/ai_n8833707/.
2. Based on Data for Census 2000 which reported 60,744 African American Iowans. More recent estimates put the number higher, but the breakdown of more recent numbers was not available for the individual census tracts. In 2000 there were 82,473 Hispanics in Iowa. By 2009 the Hispanic population in Iowa had grown to 134,402.

Discussion and Analysis

"No single epidemiologic study can be the basis for determining a causal relation between air pollution and mortality."

— Reanalysis team,
HEI Health Effects Institute, p. iv.[1]

This study assessed the spatial relationship of illness patterns to pollution released by coal plants that could be further exacerbated by the simultaneous presence of two other common sources of Iowa pollutants: CAFOs and intensive agriculture. The analysis in this social and physical environment-wide ecological study may help create hypotheses regarding the contribution of the coal plants to disease in Iowa, especially when considering how coal combustion products interact with other environmental pollutants found substantially concentrated within Iowa.

Work done by this study lays the groundwork for more specific and focused investigations in the future. This report was designed to survey publicly available data on air, water, and soil pollutants related to coal combustion and effects on human health. Areas are identified where more definitive studies can be conducted and where additional proprietary and protected public data will be worthwhile to gather. Better monitoring of air and water quality in combination with weather modeling is needed to better understand dispersion of coal combustion products from their sources. Since coal is not the only source of the pollutants considered in this study, better monitoring data and dispersion modeling of other sources may be needed. An important example of such point sources may be CAFOs. Monitoring and of air and water pollutants and mandatory reporting of emissions should consider how data can be standardized in a manner that is scientifically meaningful and useful in addition to simply satisfying legislative regulations. The absence of a clear causal relationship may have more to do with the quality of available data than the lack of such a relationship. Clearly, much more is needed to ensure that future studies can produce more definitive statements about causality.

The health data accessible in our study allows for measurement at the county level only and not a more refined, local neighborhood level. Similarly, a full model of emissions was not undertaken, yet, it is possible to make certain conclusions and predict likely public health problems. Southeast and north central Iowa stand out as hot spots for diseases of concern in this analysis. Northern border county cold spots may be a result of the fact that in these counties a significant number (up to 25%) of people are going out of state to receive treatment, thus leaving the IDPH data with undercounts. Still, hot spots are identified in southwest Iowa where out of state hospital discharges are even higher,

If one overlays an indication of the prevailing winds, as provided by wind roses,[2] over the map it is possible to recognize that a large portion of coal emissions from Mason City, Waterloo, Cedar Rapids head toward the southeast corner of the state for much of the year. Along the eastern third of the state, winds from the north and west tend to dominate, while the center third of the state is influenced more by winds from the south. Winds are as likely to sweep across Ames, Des Moines, and Marshalltown as much from the south and southeast heading toward the north central parts of the state, as they are to come from the north or west. Eastern Nebraska has four coal facilities adjacent to the three southern most Iowa counties on the Iowa-Nebraska border. These southeastern Nebraska facilities are quite close to the largest coal facility in Iowa, the Water Scott Energy Center. The Nebraska facilities are likely to add to the effects on southwestern Iowa of the Walter Scott facility.

For central Iowa some of the same factors are in play as in southwest and southeast Iowa, but here rather than other industries or traffic, the airshed is replete with coal PM that likely interacts with emissions from CAFOs and industrial agriculture. Some of the hot spot counties in north central Iowa correspond to high concentrations of CAFOs. Additionally, knowing the variability and intensity of wind in Iowa, especially from the west and south, emissions from western and central Iowa coal facilities move toward and interact with northwestern Iowa CAFO emissions and exacerbate airborne and waterborne problems in this part of the state.

Looking at all parts of the report considered, the authors feel that for many significant and costly health conditions in Iowa, coal is a serious but unacknowledged factor. Coal affects the health of Iowans as part of a suite of several factors: multiple industrial, agricultural and other sources of PM, NO_x, SO_2 combined with poverty, and related determinants of health like limited or poor health care access and services.

While the data sources that could be accessed for this study are only suggestive of an association between coal combustion pollution, each quantification of the health costs tended to underestimate the association for a variety of reasons:

A. **Aggregated Data**. Counties are not defined by natural boundaries, educational districts, economic enterprises, industries, or wind patterns. Using aggregated data at the county level may hide significant pollution related health effects for some neighborhoods. An example of an asthma hot spot missed by this study is the high rate of asthma for African Americans in Iowa's Black Hawk County.

B. **Estimated and incomplete health data.** There is a higher percentage of Iowans on the western and northern borders who traveled outside the state for health care. Thus Iowa data from these border counties could underestimate disease incidence derived from hospital discharge rates.

C. **Power output as an emissions proxy.** Estimated power output from individual plants is likely an inexact proxy for emissions because of varying plant ages, efficiencies, configuration of emissions control devices, and variations in types of coal used from time to time. The study assumed that coal emissions were static over the time period of the health data.

D. **Shared air and water from neighboring states.** Given prevailing wind patterns and weather variability, it is difficult to account for additional pollution arriving in Iowa from plants just across the Missouri River in Nebraska. Thus coal combustion pollution in Iowa further tends to be underestimated.

E. **Minority populations**. This report suggests that being of minority status in Iowa often means living close to coal plants being subject to coal based air pollutants and poor air quality. Also, minority populations face challenges in accessing health care which is likely to underestimate adverse health outcomes, at least as estimated by hospital discharge rates.

F. **The COBRA tool**. The COBRA software does not specifically identify the point source of emissions for electrical utilities that burn coal. From our research we know that some counties have coal facilities that are not reflected in the COBRA software, or in all the DNR or EIA databases. In attempting to study Johnson County, Iowa as an example, the COBRA software shows no emissions while the University of Iowa operates a power plant that burns coal. So, in this example the COBRA tool could not estimate the impact on human health resulting from operation or closure of the University of Iowa Power Plant.

Despite the identified uncertainties in this study's compiled database, the maps generated and COBRA tool provide a useful frame of reference in identifying areas requiring further attention and investigation. The data collected by this study identifies some of Iowa's local hot spots, bringing attention to them, but cannot precisely quantify the contribution of pollution from coal combustion.

Endnotes

1. Health Effects Institute. 2000. Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality: A Special Report of the Institute's Particle Epidemiology Reanalysis Project. Health Effects Institute, Cambridge MA. This report lists the major research reports on air pollution and health to 2000. Accessed 6/29/10 at http://epa.gov/ncer/science/pm/hei/Rean-ExecSumm.pdf.

2. Wind roses for 15 cities across Iowa for all 12 months are provided by Iowa Environmental Mesonet, Iowa State University Department of Agronomy. March 2009. Accessed 10/4/10 at http://mesonet.agron.iastate.edu/sites/windrose.phtml?station=DSM&network=IA_ASOS

Conclusions and Significance

"The American people have a right to air that they and their children can breathe without fear."

— Lyndon Baines Johnson

This report was motivated by the principle that the public has a right to know about toxic substances with potential to induce illness that have been introduced into the shared physical environment, whether into the airshed or watershed. This mapping project provides an entry point for health professionals and others interested in leaning more about reducing preventable diseases caused or exacerbated by the emissions and toxic waste produced when burning coal.

The study suggests that for a group of diseases recognized to be adversely affected by air, coal is a serious but unacknowledged exacerbating factor in Iowa. Coal combustion emissions combine with those from industrial, agricultural and other sources of PM, NO_X, SO_2 to adversely affect the health of Iowans. Furthermore these pollutant sources may be sited to further combine with social determinants of health especially to adversely affect minority populations in Iowa.

The authors are well aware that association is not the same as causation. This report's findings suggest the need for more careful study and response in the near future. This study has taken analysis as far as can be done with existing publicly accessible data. It will be important to acquire restricted and protected heath outcome data that has finer than county-level granularity and includes hospital discharge data from states bordering Iowa. In more advanced research, account should be taken of coal facility emissions from states bordering Iowa. Moreover, it is critical that new basic monitoring data is needed to further evaluate these important questions. A more precise study and analysis requires actual measurement of ambient air quality including particulate matter. Ideally, data on personal exposure monitoring and lung function testing is needed. Closer attention must be paid to the location of schools and effects on children. An expanded time frame should be used to allow determination of trends. And, of course, more funding is needed.

Given the complexities of environmental pollution, the incomplete database assembled for this report, and the semi-quantitative nature of emissions, this study does not point to a single source as being the most egregious in producing adverse health outcomes in Iowa. Rather, it is likely that complex interactions, unique to Iowa, of toxic emissions associated with producing energy and industrial agricultural activities leads to worsening health outcomes in Iowa. Furthermore, the changing climate with rising temperature, humidity, and precipitation conspire with the variety of emissions to create a toxic soup of the totality of air, water, and soil pollution of Iowa. Yet, the presence of coal facilities are found in relation to each of the "hot spots" in Iowa for a set of preventable diseases that are known to be exacerbated by coal combustion pollution.

We can do much better. As indicated by the number of exceedances for air quality standards, Iowa has several counties close to upper limits at risk of being officially found to out of compliance and sanctioned for nonattainment of current national $PM_{2.5}$ standards. Take note, current standards elsewhere like California, Canada, and the European Union are more strict than U.S. national standards.[1] World Health Organization recommended standards are still more strict than all these. Considering these trends, even when Iowa is in attainment with the current U.S. standards, further tightening of standards is inevitable.

Predictable illness as a result of doing business is not just an externality to be overlooked by business and a problem to addressed only by affected individuals. These costs can and should be internalized by the coal-burning electricity industry as part of the cost of doing business. Despite difficulties in ascertaining or assigning specific causation, the likelihood that combustion emission related factors produce or exacerbate chronic diseases can no longer be overlooked. Even in this study based on existing but incomplete epidemiological and geographical measures, environmental factors can be found with significant effect sizes comparable to those found in peer reviewed scientific literature.

This investigation is offered as another of the emerging answers to questions regarding the true costs to the human family of continued reliance on fossil fuels, especially coal. These risks are unjustified considering that less polluting options for energy production from natural gas to the many benign renewable energy technologies ready for use today–wind, solar, geothermal and biomass–that are readily applicable to Iowa.

Endnotes

1. For a more complete description of the air quality monitoring similarities and differences between the EU and the US see: Danish National Environmental Research Institute. *Comparison of the EU and US Air Quality Standards & Planning Requirements 4 Oct 04*. 58 pgs. Accessed 6/24/10 at http://ec.europa.eu/environment/archives/cafe/activities/pdf/case_study2.pdf.

Getting Beyond Coal in Iowa

"Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house."

— Henri Poincaré

Often societies must act without all scientific answers definitively in hand. Paralleling the evidence regarding the toxic health effects of coal combustion are other compelling lines of scientific findings. An example is the evidence for anthropogenic global warming through accelerating accumulation of greenhouse gases in the atmosphere with consequent global warming and climate change. The effect on Iowa's climate includes increasing precipitation and humidity, both of which accelerate entry of coal combustion toxic emissions into the watershed and exacerbate chemical reactions in the atmosphere that create small and dangerous particulate matter. Science can provide building blocks as a foundation for action, but in the end action must be taken.

Among U.S. states, Iowa imports and burns disproportionately more coal and burns it in some of the oldest and least efficient facilities in the nation. To reduce Iowa's dependence on imported coal and disproportionate burden of associated health costs, Iowa has a number of options.

The following will be effective in reducing dependence on coal, reducing human and environmental harms, and saving health dollars. For example, Iowa can:

- choose to raise and enforce standards for renewable energy;
- raise and enforce standards for energy efficiency;
- increase funding for effective energy efficiency programs;
- refuse to permit new coal plants, or allow existing plants to expand;
- shut down the oldest and/or least efficient (dirtiest) coal plants;
- lower annual standards for PM2.5 to at least those of California, taking more aggressive action than the federal government, and apply to existing air permits with no grandfathering;
- designate that the Iowa Department of Natural Resources and Iowa Department of Public Health join efforts to incorporate public health standards in the permitting, compliance and regulatory process governing Iowa air standards.

State efforts alone are insufficient; pollution and health risks do not honor state lines. State by state projects can be cumbersome, confusing and ineffective. State efforts alone are also notorious for inviting polluters to pursue business in the least regulated states. Efforts to provide energy while protecting public health and our shared environment must be national.

In order to protect public health, the federal government should:

- limit subsidies to fossil fuel sourced energy, including subsidies for the extraction and combustion of coal, coal gasification, and pollution control technology;
- discourage emissions by putting a price on carbon that encourages utilities to reduce their use of fossil fuels, especially coal;
- pass stable, long-term policies to increase the deployment of renewable energy sources , including increased funding for research and development, as well as a renewable electricity standard (RES), tax and financial incentives;
- aggressively promote implementation of strong energy efficiency measures, including building codes, appliance and equipment standards, and an energy efficiency resource standard for electricity providers.

Similarly, state and federal agencies need to address the coal combustion waste (CCW) issue systematically and comprehensively. The toxicity of CCW should no longer be ignored. Definitions matter, and surface disposal is not a "beneficial use" of this toxic waste product considering the potential public health impact. Close monitoring of the most mobile sentinel molecules such as sulfate, iron, manganese, calcium, magnesium, sodium, and chloride is needed which serve as markers for leaking CCW sites. Detection of unsafe CCW sites must lead to mandated action.

Specific recommendations for the management of CCW include:[1]

- discontinue the practice of allowing CCW to be used for land development and instead dispose of it in landfills that require liners and other precautions to prevent leaching into ground or surface water;
- provide publicly available groundwater monitoring at existing active structural fill sites for at least 30 years after a structural fill is closed;
- require cleanup by developers if monitoring data reveal that groundwater or surface water has been

contaminated by coal ash;

- require that the use of coal ash as structural fill be permanently recorded on the deed for the affected property.

Finally, important for many reasons and beyond evaluating the coal issue, is the need to carefully monitor significant health events. As has been indicated throughout this report, the quality of data on Iowa's disease incidence and trends could be described as uneven at best. Given the clear link between air quality and human health, the State of Iowa should improve data collection that relates to air quality and adverse health effects. The science that informs policy and many tools like the EPA's COBRA software and others rely on such data.

None of these recommendations are simple, quick, or easy. Acting on these options require increased public funding to enable adequate monitoring to support regulatory oversight and enforcement, and as demonstrated, effectively lower healthcare costs over the longer term. Long term thinking coupled with judicious spending now will pay back many-fold in the future. Efforts have already begun in some Iowa farming communities and on Iowa's college campuses.[2] But it will take efforts at all levels, local, state, regional, national and international to bring about the changes most urgently needed to protect all members of the human family.

Endnotes

1. Several of these recommendations are more completely described in "Unlined Landfills?: The Story of Coal Ash Waste in our Backyard" Sierra Club North Carolina Report, April 7, 2010. Accessed 8/1/10 at http://nc.sierraclub.org/work/docs/FINAL_coal_ash_report.pdf.
2. Lane, Sam. Some concerned about UI's use of coal boilers. *Daily Iowan*. Accessed 8/1/10 at http://www.dailyiowan.com/2010/05/10/Metro/17244.html.

Postscript

"Eventually we'll realize that if we destroy the ecosystem, we destroy ourselves."

— Jonas Salk,
American physician and microbiologist

There was a tragic explosion at Massey Energy's Upper Big Branch Mine in Raleigh County, West Virginia on April 5, 2010 where 25 coal miners died. A month later the explosion on BP's Deepwater Horizon Rig in the Gulf of Mexico triggering an unprecedented oil well blowout one mile below the Gulf's surface rapidly became an uncontrolled disaster. Crude oil from the geyser expanded across the Gulf of Mexico over the next three months creating the worst environmental disaster in U.S. history affecting Gulf wildlife and economy. U.S. citizens might do well to ponder what is driving these increasingly dangerous and desperate efforts to extend our unsustainable fossil fuel dependent life style.

This is so for Iowans, as well as the rest of the nation. Even though these events, are unfolding at a great distance, Iowans may not recognize their role and connection to these complex and remote events including the real risks to themselves.[1] Iowans depend primarily on coal and petroleum for energy just like the rest of the country; and by some measurements, as indicated in this report, even more so than most other parts of the country.

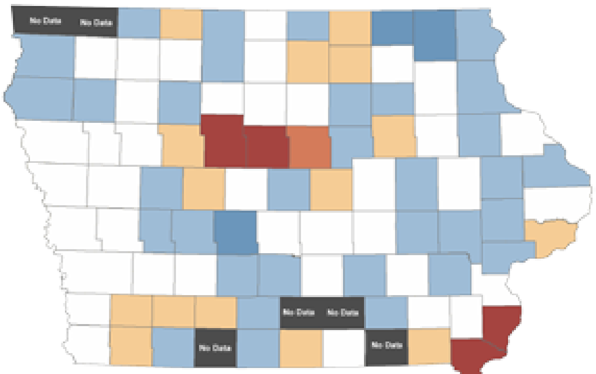
The authors hope this report, that assesses hidden health impacts borne by Iowans because of their dependence on fossil fuels, especially coal, helps to expose overlooked costs of burning coal to generate electricity in Iowa and elsewhere. As noted in the policy statement of the American Academy of Pediatrics, important action can be also taken by physicians to reduce the exposures and effects of air pollution in our children[2] Physicians and other health care providers can do much to protect the health of their patients, not only by educating them about healthy behaviors and treating illness, but also by educating policy makers about the need for cleaner air, specifically of the need to replace coal with clean and sustainable alternative energy sources.

Endnotes

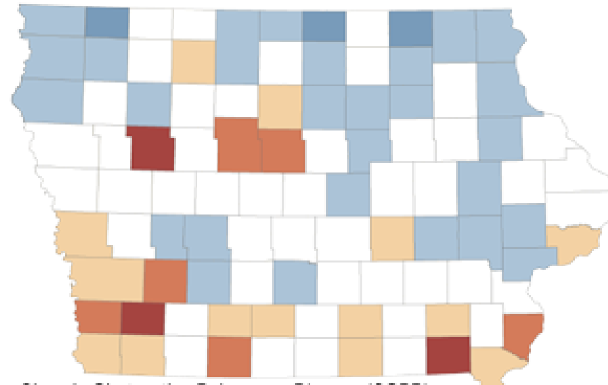
1. During two focus groups held in Des Moines in early 2010 by the Iowa Chapter of Physicians for Social Responsibility (unpublished), virtually none of the randomly recruited participants expressed any knowledge about health risks or concerns about coal based electric power. The groups uniformly agreed that coal combustion to generate electricity was an affordable public good.

2. Ambient Air Pollution: Health Hazards to Children. Committee on Environmental Health. *Pediatrics* 2004. 114;1699-1707. Accessed 7/3/10 at http://pediatrics.aappublications.org/cgi/reprint/114/6/1699.pdf.

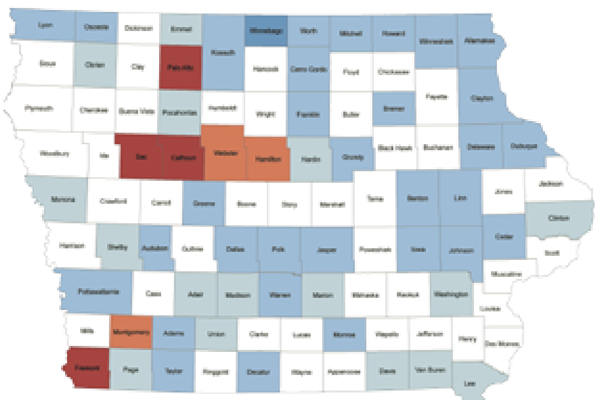
Appendix I: Iowa Hospital Discharges by County



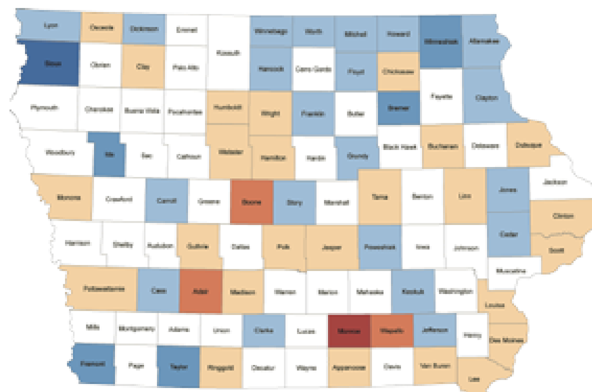
Asthma



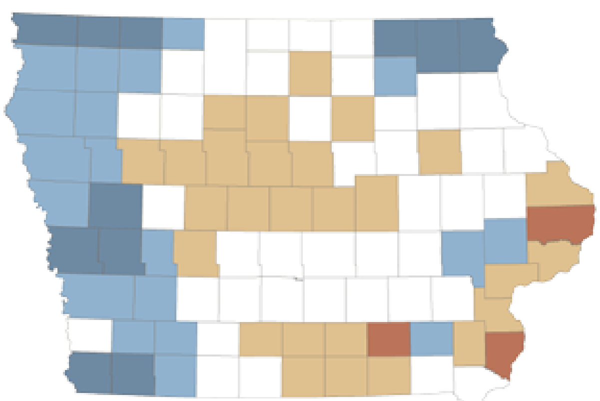
Chronic Obstructive Pulmonary Disease (COPD)



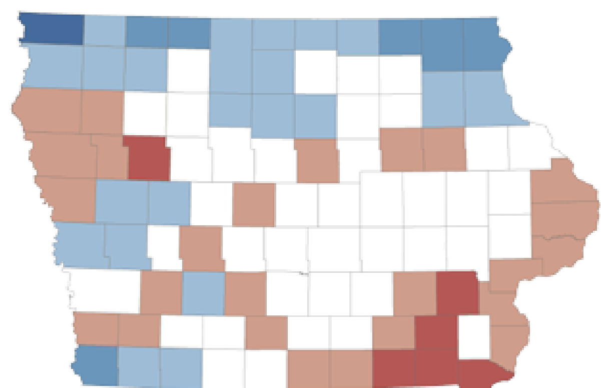
Influenza & Pneumonia



Respiratory Cancer



Coronary Heart Disease



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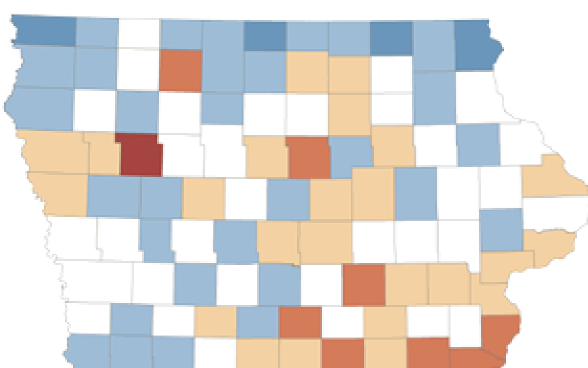


Diabetes

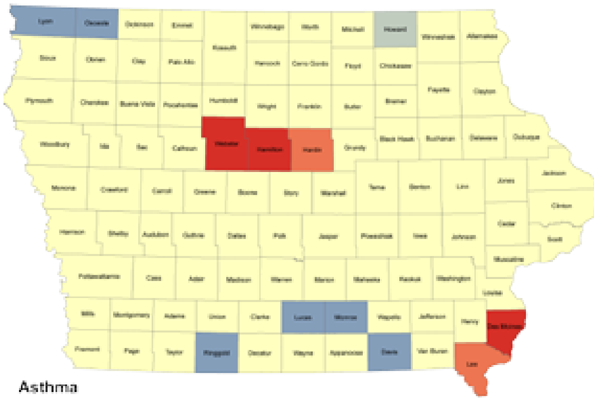
Iowa Hospital Discharges by County 2004-2006

(per 10,000 population)

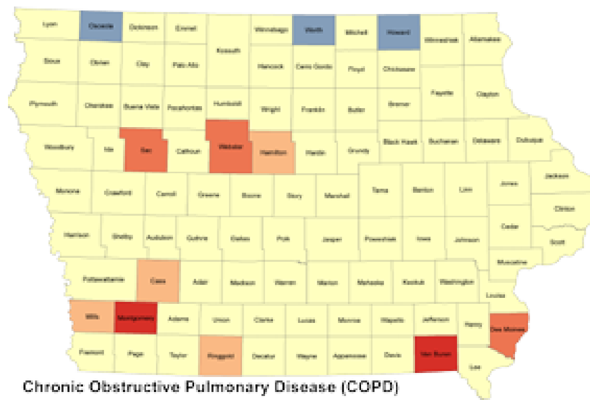
Color Key: Standard deviations from the state mean

- < -2.5
- -2.5 - -1.5
- -1.5 - -0.50
- -0.50 - 0.50
- 0.50 - 1.5
- 1.5 - 2.5
- > 2.5

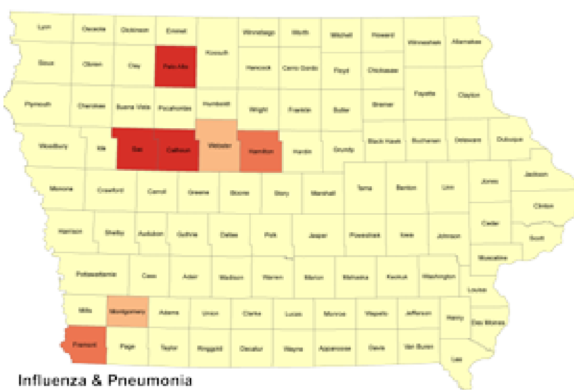
Appendix II: Cluster Analysis for Local Hot/Cold Spots



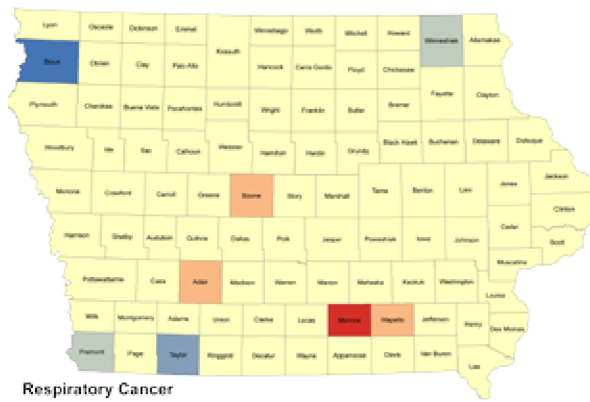
Asthma



Chronic Obstructive Pulmonary Disease (COPD)



Influenza & Pneumonia



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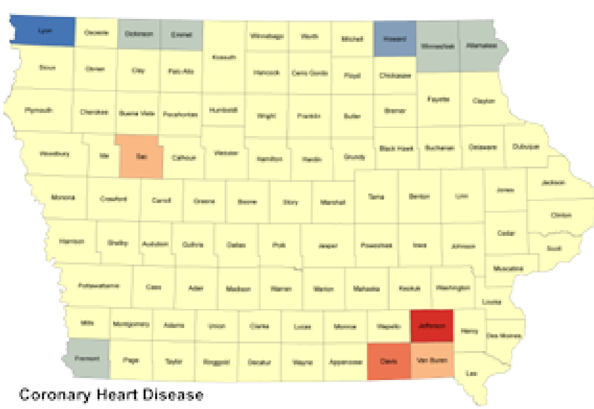
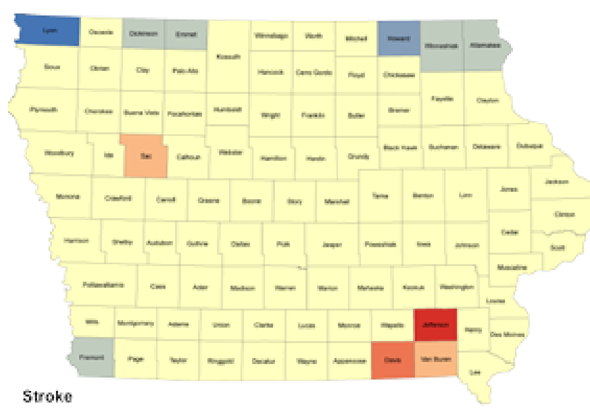


Coronary Heart Disease



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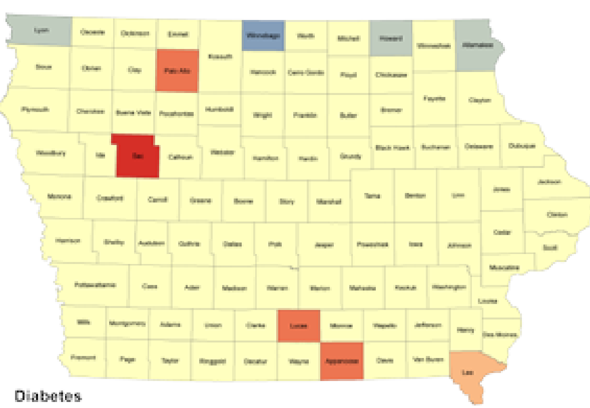

Diabetes

Cluster Analysis for Local Hot/Cold Spots.
Combined for: asthma, COPD, respiratory infections, respiratory cancer, coronary heart disease, and stroke.

Color Key:
Gedis-Ord Gi Total Z-scores.
A Positive Z-score indicates local a hot spot county (increased incidence.) A negative Z-score indicates a local cold spot county (decreased incidence.)

- < -2.58
- -2.58 - -1.96
- -1.96 - -1.65
- -1.65 - 1.65
- 1.65 - 1.96
- 1.96 - 2.58
- > 2.58

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