Population and Exposure Characteristics of Coal Mining and Non-Coal Mining Counties in West Virginia

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ABSTRACT

The objective of this study was to provide a description of the demographic information, amount of coal production, the distribution of cardiovascular and respiratory hospitalizations, and environmental exposures by county in West Virginia. In order to make this assessment, the state was divided into two groups, coal mining counties and non-coal mining counties, based on the presence of coal production in 2005 identified from the West Virginia Office of Miners' Safety and Training report. There were marked differences in rates of hospitalizations between coal and non-coal counties, but as this initial effort is ecological and descriptive in nature, statistical tests for differences between coal mining and non-coal mining counties were not conducted.

INTRODUCTION

There is a very large and significant literature related to occupational exposures in the coal mining industry. Exposures such as occupational noise exposure, accidental injuries, bronchial and respiratory exposure due to coal dust, and increased risk of lung and stomach cancer are well documented in early studies (Coggon 1998; Donoghue 2004; Fernández-Navarro 2012). Relatively few investigations have considered the relationship between residential proximity to coal mining sites (underground and surface) and health outcomes (Howel 2001). In such studies to date, the metric most often employed to define exposure has been annual volume of coal production (Hendryx 2007). No studies have reported on a comparison of information on exposures to ambient air pollutants within proximity to the community itself or have considered exposures of other industries within these communities.

Using individual pollutants as environmental exposures is the next step in the progression of investigating possible associations to the health and well-being of coal mining communities in West Virginia (WV). This study is an exploration of population features, coal production, health outcomes, and environmental exposures of the state as a whole and by county in order to provide an overview of exposure and health characteristics of WV coal mining and non-coal mining counties. These descriptions will inform future health studies.

WEST VIRGINIA DEMOGRAPHICS AND COAL PRODUCTION

Table 1 contains for the state of WV and each county, information on population, the total number of residents who work in the coal

Table 1. West Virginia population characteristics by county

County	Coal Mining 2005 (Y/N)*	Population (per 2011 Census Estimate)†	# Employed in Coal Mining Industry (%)*	% Non-white†	% 65+†
Statewide		1,855,364	17,992 (1.0)	5.9	16.2
Barbour	Y	16,520	176 (1.1)	3.2	16.8
Boone	Y	24,444	3,614 (14.8)	1.4	14.3
Braxton	Y	14,485	118 (0.8)	1.9	17.7
Brooke	Y	23,844	34 (0.1)	3.0	19.0
Clay	Y	9,357	146 (1.6)	1.4	16.1
Fayette	Y	45,699	507 (1.1)	6.4	16.8
Grant	Y	11,891	127 (1.1)	2.0	19.0
Greenbrier	Y	35,800	77 (0.2)	5.1	19.4
Harrison	Y	69,436	650 (0.9)	4.0	16.7
Kanawha	Y	192,315	1,512 (0.8)	10.8	16.8
Lincoln	Y	21,550	88 (0.4)	1.0	15.3
Logan	Y	36,457	1,347 (3.7)	3.5	15.5
Marion	Y	56,586	568 (1.0)	5.6	17.0
Marshall	Y	32,800	1,189 (3.6)	2.0	17.5
McDowell	Y	21,729	947 (4.4)	10.6	16.6
Mercer	Y	62,465	7 (0.01)	8.4	18.0
Mineral	Y	28,192	12 (0.04)	4.8	17.7
Mingo	Y	26,563	1,551 (5.8)	3.2	13.8
Monongalia	Y	98,528	1,064 (1.1)	8.9	10.2
Nicholas	Y	26,268	459 (1.7)	1.8	17.5
Preston	Y	33,723	236 (0.7)	2.4	16.2
Raleigh	Y	79,127	1,136 (1.4)	11.1	16.1
Randolph	Y	29,465	61 (0.2)	2.7	18.3
Tucker	Y	7,021	30 (0.4)	1.4	20.9
Upshur	Y	24,322	327 (1.3)	2.4	16.9
Wayne	Y	42,126	422 (1.0)	1.5	17.0
Webster	Y	9,143	347 (3.8)	1.5	17.8
Wyoming	Y	23,419	1,240 (5.3)	1.9	15.3
Berkeley	N	105,750		11.1	11.7
Cabell	N	96,653		8.4	15.9
Calhoun	N	7,652		1.6	18.5
Doddridge	N	8,171		3.1	15.8
Gilmer	N	8,705		15.9	14.0
Hampshire	N	23,812		2.7	16.9
Hancock	N	30,571		4.1	18.9
Hardy	N	13,912		4.9	17.2
Jackson	N	29,241		1.8	17.7
Jefferson	N	54,225		10.9	12.2
Lewis	N	16,416		2.2	18.3
Mason	N	27,298		2.4	17.3
Monroe	N	13,534		2.6	20.1
Morgan	N	17,535		3.0	19.0
Ohio	N	44,246		6.7	18.4

(table continues)

Table 1. West Virginia population characteristics by county (continued)

County	Coal Mining 2005 (Y/N)*	Population (per 2011 Census Estimate)†	# Employed in Coal Mining Industry (%)*	% Non-white†	% 65+†
Pendleton	N	7,673		3.8	22.5
Pleasants	N	7,611		2.8	16.4
Pocahontas	N	8,786		2.3	19.6
Putnam	N	56,008		3.2	14.7
Ritchie	N	10,295		1.4	17.9
Roane	N	14,858		1.7	17.8
Summers	N	13,867		7.0	19.6
Taylor	N	16,916		2.4	16.1
Tyler	N	9,121		1.3	18.7
Wetzel	N	16,351		1.2	19.8
Wirt	N	5,762		1.7	15.9
Wood	N	87,120		3.4	17.1

* WV Office of Miners' Health Safety and Training, 2005 Coal Production by County.
† US Census Bureau.

mining industry, the percent of residents who are non-white, and the percent of residents who are 65 years of age and older. 'Coal Mining' is defined as any active mining in 2005 per the WV Office of Miners' Safety and Training (http://www.wvminesafety.org/cnty2005.htm) report. Population and demographic information was identified using the 2010 US Census (http://quickfacts.census.gov/qfd/states/54000.html). The number of residents who work in the coal mining industry was provided by the 2005 WV Office of Miners' Safety and Training (http://www.wvminesafety.org/cnty2005.htm) report and is only available for counties that mine coal, although it is reasonable to assume that there are employees of coal mines who reside in non-coal mining counties. The total population of WV is 1,855,364, with 1,103,275 (59.5%) residing in coal mining communities and 752,089 residing in non-coal mining areas.

Kanawha County is the most populous in WV with 10.4% of the total population. Boone County has the highest percentage of residents who are employed by the coal mining industry (14.8%). The average proportion of non-white residents in coal mining counties is 4.1% and ranges from 1.0–11.1%, compared to 4.2% with a range from 1.2–15.9% in non-coal mining counties. The average proportion of residents 65 years of age or older in coal mining counties is 16.8% (range 10.2–20.9%) in non-coal mining counties the average proportion is 17.3% (range 11.7–22.5%). A total of 16.2% of West Virginians are aged 65 and older which is considerably higher than the national average level of 13.3% (US Census, 2010). Overall the proportion of individuals over 65 is very similar in the coal and non-coal mining counties.

Table 2 provides coal production information for the state of WV as a whole and by county. The production amounts are given as a breakdown, in tons, of surface mining, underground mining, and total production for 2005 (http://www.wvminesafety.org/cnty2005.htm). Total coal mining by county can also be found in Figure 1. WV is a major coal producing state both for surface and underground coal production. Boone County had the highest coal mining production of any WV county in 2005. With almost 20% of the entire state's production, Boone County had more than twice the production of any other county. Kanawha and Marshall Counties are the second and third highest coal producing counties in WV respectively. Statewide, WV produced more than 1.5 times the amount of coal from underground mining than

Table 2. 2005 West Virginia coal production by type and county

County	Surface Mining–Tons* (% of Total)	Underground Mining–Tons* (% of Total)	Total Mining–Tons*
Statewide	60,891,662 (38.2)	98,606,407 (61.8)	159,498,069
Barbour	146,579 (16.3)	752,190 (83.7)	898,769
Boone	15,589,659 (50.9)	15,058,730 (49.1)	30,648,389
Braxton	0	1,153,785 (100)	1,153,785
Brooke	220,638 (100)	0	220,638
Clay	3,942,353 (100)	0	3,942,353
Fayette	2,240,474 (61.0)	1,432,766 (39.0)	3,673,240
Grant	0	269,207 (100)	269,207
Greenbrier	0	401,573 (100)	401,573
Harrison	109,852 (1.6)	6,716,569 (98.4)	6,826,421
Kanawha	5,632,859 (39.3)	8,692,381 (60.7)	14,325,240
Lincoln	22,174 (2.6)	839,743 (97.4)	861,917
Logan	9,508,489 (73.5)	3,431,698 (26.5)	12,940,187
Marion	94,367 (1.5)	6,359,281 (98.5)	6,453,648
Marshall	0	13,924,916 (100)	13,924,916
McDowell	2,240,730 (45.9)	2,636,742 (54.1)	4,877,472
Mercer	17,738 (26.8)	48,534 (73.2)	66,272
Mineral	93,316 (100)	0	93,316
Mingo	7,276,897 (54.1)	6,165,813 (45.9)	13,442,710
Monongalia	432,756 (4.1)	10,229,601 (95.9)	10,662,357
Nicholas	3,420,643 (84.2)	641,339 (15.8)	4,061,982
Preston	20,144 (1.3)	1,509,216 (98.7)	1,529,360
Raleigh	3,374,763 (34.1)	6,507,617 (65.9)	9,882,380
Randolph	0	473,571 (100)	473,571
Tucker	0	114,582 (100)	114,582
Upshur	7,101 (0.6)	1,191,323 (99.4)	1,198,424
Wayne	813,279 (16.3)	4,191,105 (83.7)	5,004,384
Webster	3,403,298 (69.9)	1,462,088 (30.1)	4,865,386
Wyoming	2,283,553 (34.2)	4,402,037 (65.8)	6,685,590

* WV Office of Miners' Health Safety and Training, 2005 Coal Production by County.

from surface mining in 2005. However, this ratio varies greatly from county to county, with most counties having both surface and underground mines. Brooke, Clay, and Mineral counties have their entire coal production from surface mines. Braxton, Grant, Greenbrier, Marshall, Randolph and Tucker counties have their entire coal production from underground mines.

WEST VIRGINIA HOSPITALIZATIONS

The WV Health Care Authority provided hospitalization data for the entire state of West Virginia from 2005–2009. Table 3 contains counts of circulatory hospitalizations (ICD-9 codes 390–459.9) and respiratory hospitalizations (ICD-9 codes 460–519.9) by county for 2007. Using the population data found in Table 1, Table 3 also includes crude rates, which do not take the age distribution of the population into account, by county for these outcomes. Statewide, there were 23.6/1000 hospitalizations for circulatory diseases. These ranged from 7.0 (Mineral County) to 40.7 (Logan County) in coal mining counties and from 2.4 (Hampshire County) to 45.2 (Lewis County) in non-coal mining counties. For respiratory diseases, the statewide hospitalization rate was 15.9/1000. For coal mining counties, the range was from 7.0 (Monongalia County) to 35.5

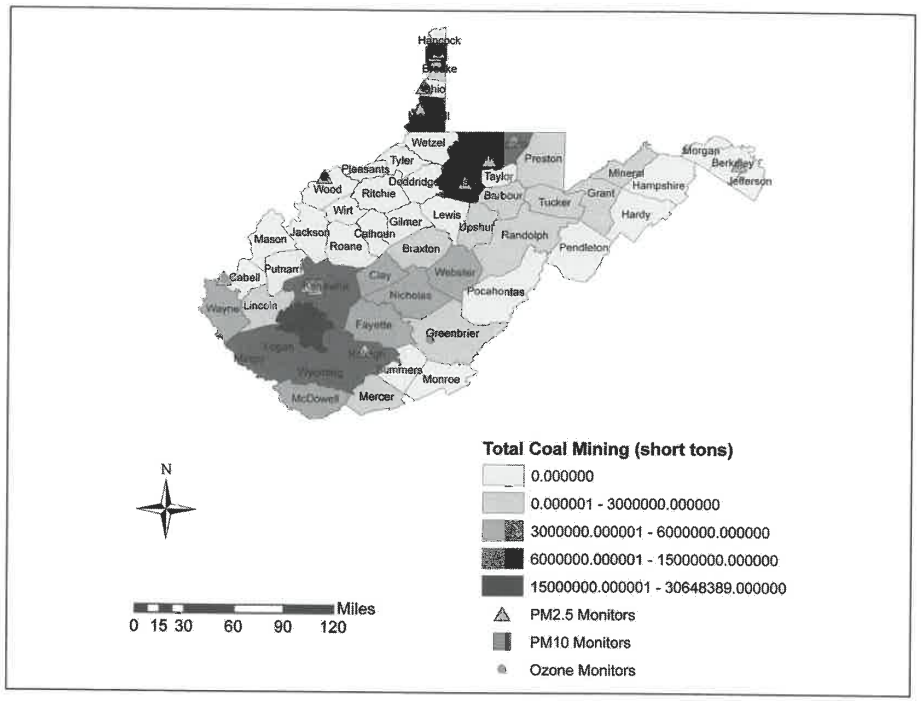

Figure 1. Air monitors and coal production by county in West Virginia, 2005

(Logan County) and for non-coal mining counties the range was from 3.4 (Hampshire County) to 29.9 (Lewis County).

EXPOSURES

The location of Criteria Air Pollutant (CAP) monitors in WV was provided by the US EPA (http://www.epa.gov/reg3artd/airquality/r3monitors-tabular.htm) and is shown in Figure 1. There are currently 5 PM_{10} monitors, 14 $PM_{2.5}$ monitors, and 8 ozone monitors throughout the state. These are typically placed near high traffic areas and significant point sources of ambient pollution.

PM, at both the less than 10 μm in diameter (PM_{10}) and less than 2.5 μg in diameter ($PM_{2.5}$) sizes, is measured and regulated by the EPA. Major sources of PM are industrial and vehicular. The current standard for PM_{10} is 150 μg/m^3, not to be exceeded in a 24-hour span more than once per year, on average, over 3 years. The current standard for $PM_{2.5}$ is 35 μg/m^3 for the 98th percentile averaged over 3 years, or a 15 μg/m^3 annual mean averaged over 3 years (http://www.epa.gov/air/criteria.html). The average annual level of $PM_{2.5}$ by county for West Virginia in 2005 can be seen in Figure 2. These data were provided by the CDC's Environmental Tracking Network (http://ephtracking.cdc.gov/QueryPanel/EPHTNQuery/EPHTQuery.html). Clearly, high $PM_{2.5}$ levels coincide with urban areas of WV. The coal mining counties (in bold) have heterogeneous concentrations of $PM_{2.5}$. Although Boone County is the highest coal producing county in the state, it had mid-range $PM_{2.5}$ concentration. In 2005, Brooke and Kanawha Counties exceeded the 15 μg/m^3 limit. There are multiple sources of $PM_{2.5}$ including both vehicular traffic and industrial emissions based on fossil fuel combustion.

Table 3. 2007 West Virginia circulatory and respiratory hospitalizations by county

County	Coal Mining 2005 (Y/N)*	# Circulatory Hospitalizations†,‡	Crude Circulatory Hospitalization Rate (per 1,000)	# Respiratory Hospitalizations†,§	Crude Respiratory Hospitalization Rate (per 1,000)
Statewide		43,725	23.6	29,420	15.9
Barbour	Y	406	24.6	346	20.9
Boone	Y	741	30.3	499	20.4
Braxton	Y	271	18.7	179	12.4
Brooke	Y	428	18.0	343	14.4
Clay	Y	316	33.8	196	20.9
Fayette	Y	1,452	31.8	946	20.7
Grant	Y	154	13.0	114	9.6
Greenbrier	Y	767	21.4	563	15.7
Harrison	Y	1,993	28.7	1,542	22.2
Kanawha	Y	5,698	29.6	2,987	15.5
Lincoln	Y	555	25.8	370	17.2
Logan	Y	1,483	40.7	1,296	35.5
Marion	Y	1,781	31.5	1,024	18.1
Marshall	Y	936	28.5	529	16.1
McDowell	Y	522	24.0	486	22.4
Mercer	Y	1,483	23.7	1,497	24.0
Mineral	Y	198	7.0	205	7.3
Mingo	Y	753	28.3	837	31.5
Monongalia	Y	1,530	15.5	690	7.0
Nicholas	Y	629	23.9	458	17.4
Preston	Y	795	23.6	391	11.6
Raleigh	Y	3,034	38.3	1,765	22.3
Randolph	Y	872	29.6	717	24.3
Tucker	Y	143	20.4	85	12.1
Upshur	Y	579	23.8	327	13.4
Wayne	Y	819	19.4	605	14.4
Webster	Y	224	24.5	178	19.5
Wyoming	Y	708	30.2	503	21.5
Berkeley	N	793	7.5	566	5.4
Cabell	N	1,856	19.2	1,290	13.3
Calhoun	N	158	20.6	104	13.6
Doddridge	N	137	16.8	73	8.9
Gilmer	N	272	31.2	163	18.7
Hampshire	N	56	2.4	81	3.4
Hancock	N	792	25.9	609	19.9
Hardy	N	102	7.3	74	5.3
Jackson	N	850	29.1	627	21.4
Jefferson	N	323	6.0	312	5.8
Lewis	N	742	45.2	491	29.9
Mason	N	912	33.4	521	19.1
Monroe	N	280	20.7	240	17.7
Morgan	N	113	6.4	134	7.6
Ohio	N	1,174	26.5	800	18.1
Pendleton	N	72	9.4	53	6.9

(table continues)

Table 3. 2007 West Virginia circulatory and respiratory hospitalizations by county (continued)

County	Coal Mining 2005 (Y/N)*	# Circulatory Hospitalizations†,‡	Crude Circulatory Hospitalization Rate (per 1,000)	# Respiratory Hospitalizations†,§	Crude Respiratory Hospitalization Rate (per 1,000)
Pleasants	N	137	18.0	100	13.1
Pocahontas	N	168	19.1	174	19.8
Putnam	N	1,148	20.5	580	10.4
Ritchie	N	244	23.7	180	17.5
Roane	N	342	23.0	177	11.9
Summers	N	329	23.7	205	14.8
Taylor	N	324	19.2	197	11.6
Tyler	N	208	22.8	117	12.8
Wetzel	N	595	36.4	293	17.9
Wirt	N	141	24.5	94	16.3
Wood	N	2,187	25.1	1,487	17.1

* WV Office of Miners' Health Safety and Training, 2005 Coal Production by County
† West Virginia Health Care Authority
‡ ICD-9 codes 390–459.9
§ ICD-9 codes 460–519.9

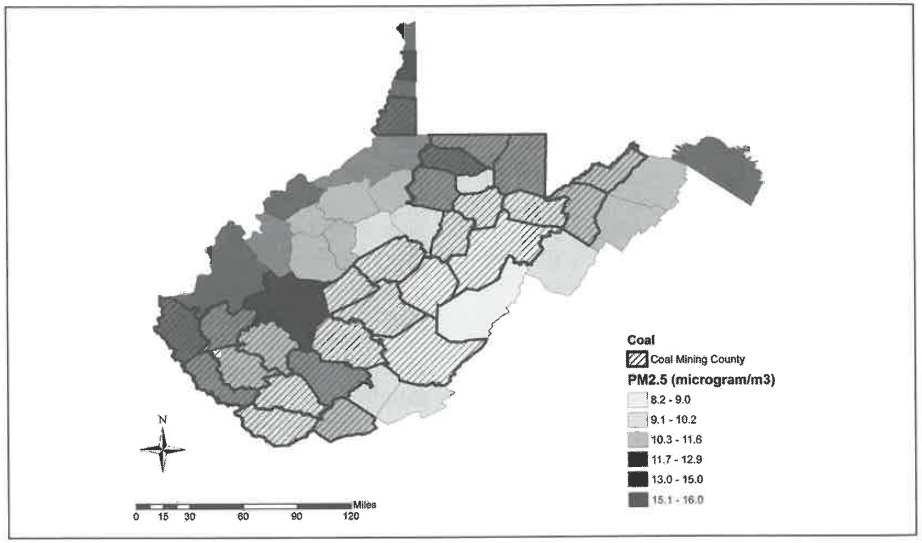

Figure 2. Monitored and modeled average annual $PM_{2.5}$ by county in West Virginia, 2005

There are several sources of information on exposures available by county, census tract and by location that can be used to quantify potential exposures in WV. These represent all sources both vehicular and industrial including coal mining related exposures. Table 4 presents the results of a literature search for coal mining related exposures. For purposes of this current study, four example exposures were investigated: lead, arsenic, cadmium, and particulate matter (PM).

Table 4. Possible exposures of interest

Pollutant	Ref1*	Ref2	Ref3	Ref4	Ref5	Ref6	Ref7	Ref8	Ref9	Data Available
PM	✓							✓	✓	✓†
Ozone										✓†
Lead		✓			✓	✓				✓‡
Arsenic		✓	✓							✓‡
Cadmium					✓	✓				✓‡
PAH							✓		✓	✓‡
Chromium				✓	✓					✓‡
Nickel		✓			✓					✓‡
NO_x										
Benzene										✓‡
Selenium		✓	✓							✓‡
Diesel PM									✓	✓‡
Aluminum	✓	✓								
Calcium	✓	✓			✓					
Iron	✓	✓		✓	✓	✓				
Potassium	✓	✓								
Magnesium	✓	✓			✓					
Sodium	✓	✓			✓					
Titanium	✓	✓								
Zinc	✓	✓		✓	✓	✓				
Sulfate/sulfur	✓	✓								
Silicates/silicon		✓			✓					
Chlorine		✓								✓‡
Phosphorus		✓			✓					✓‡
Manganese		✓			✓	✓				✓‡
Copper		✓		✓	✓	✓				
Bromine		✓								
Strontium		✓			✓					
Gallium		✓			✓					
Zirconium		✓			✓					

* Ref = reference.
† EPA air monitors.
‡ 2005 NATA.

1. Knuckles TL, Stapleton PA, Minarchick VC, Esch L, McCawley M, Hendryx M, et al. 2012. Air pollution particulate matter collected from an Appalachian mountaintop mining site induces microvascular dysfunction. *Microcirculation*. Doi: 10.1111/micc.12014.
2. Lee CY, Lee SL, Sheehan CE and Wang Y. 1996. *Composition of coal dusts and their cytotoxicity on alveolar macrophages.* US. Army Armament Research, Development and Engineering Center. Technical Report ARCCB-TR-96026.
3. Ebdon L and Wilkinson JR. 1987. The determination of arsenic and selenium in coal by continuous flow hydride-generation atomic absorption spectrometry and atomic fluorescence spectrometry. *Analytica Chimica Acta*. 194: 177–187.
4. Dalal NS, Newman J, Pack D, Leonard S and Vallyathan Val. 1995. Hydroxyl radical generation by coal mine dust: possible implication to coal workers' pneumoconiosis (CWP). *Free Radical Biology & Medicine*. 18(1):11–20.
5. Freedman RW and Sharkey AG. 1972. Recent advances in the analysis of respirable coal dust for free silica, trace elements, and organic constituents. *Annals of the New York Academy of Sciences*. 200:7–16.
6. Spencer S. 2001. Effects of coal dust on species composition of mosses and lichens in an arid environment. *Journal of Arid Environments*. 49:843–853.
7. Yunker MB, Macdonald RW, Vingarzan R, Id R, Mitchell H, Goyette D, et al. 2002. PAHs in the Fraser River basin: a critical appraisal of PAH ratios as indicators of PAH source and composition. *Organic Geochemistry*. 33:489–515.
8. Pless-Mulloli T, King A, Howel D, Stone I, Merefield J. 2000. PM_{10} levels in communities close to and away from opencast coal mining sites in Northeast England. *Atmospheric Environment*. 34:3091–3101.
9. Litton CD. 2002. Studies of the measurement of respirable coal dusts and diesel particulate matter. *Measurement Science and Technology*. 13:365–374.

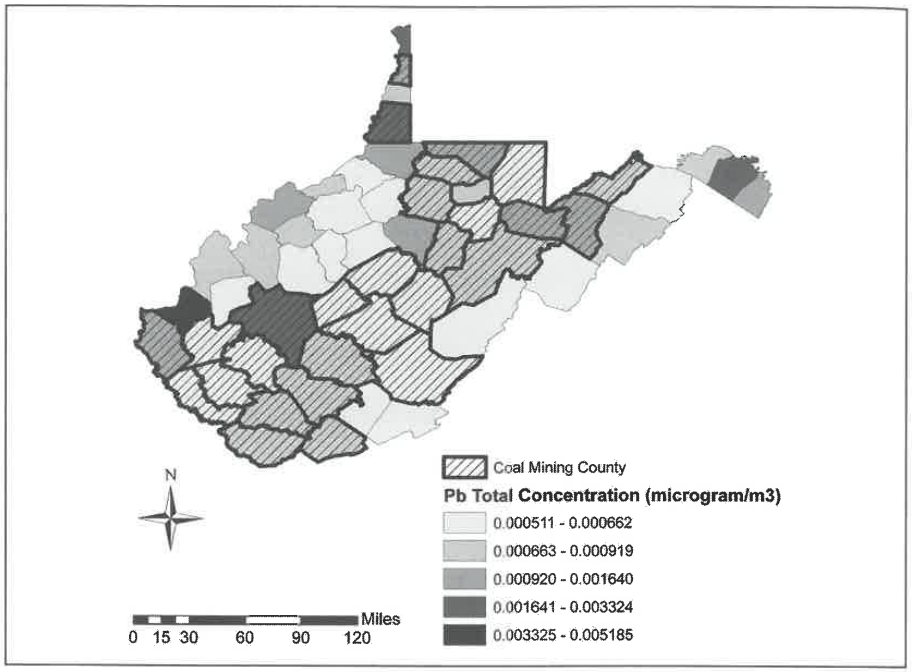

Figure 3. Lead concentrations by county in West Virginia (per 2005 NATA)

Lead, arsenic, and cadmium have all been associated with coal mining (Table 4) as they are natural constituents of coal and of the earth's crust. Levels of these pollutants have been modeled by the EPA for the National-scale Air Toxics Assessment (NATA). NATA uses information from emission sources (both stationary and mobile) to estimate ambient exposures of 187 hazardous air pollutants. These reports have been published for the years 1996, 1999, 2002, and 2005 (http://www.epa.gov/ttn/atw/natamain/). Maps of ambient air levels of lead, arsenic, and cadmium (estimated by the 2005 NATA) by county in WV can be found in Figures 3, 4, and 5, respectively. These three figures illustrate that coal mining counties run through the center of the state of WV, and have varying levels of lead, arsenic, and cadmium. Counties with coal mining have exposure levels of these pollutants which range from the lowest concentrations to the highest concentrations detected in WV. Boone County, the highest coal producing county in WV, is in the lowest concentration range of lead, arsenic, and cadmium. The second and third highest coal producing counties (Kanawha and Marshall) are in the mid to high ranges for these pollutants.

However, NATA estimates are known to underestimate exposures and are not meant to be compared to regulatory standards (Talbott 2011). Of these three air pollutants, only lead is EPA monitored and regulated. By this standard, the average level of lead over a three month period is not to exceed 0.15 $\mu g/m^3$ (http://www.epa.gov/air/criteria.html). For reference, the 2005 annual mean of air lead measured from the one CAP monitor (located in Ohio County) in WV that measures this pollutant was 0.0100 ± 0.0066 $\mu g/m^3$. This one monitor represents a "ground level" reading yearly average for this one area in Ohio County.

Although the EPA does not have a standard for arsenic or cadmium, the California

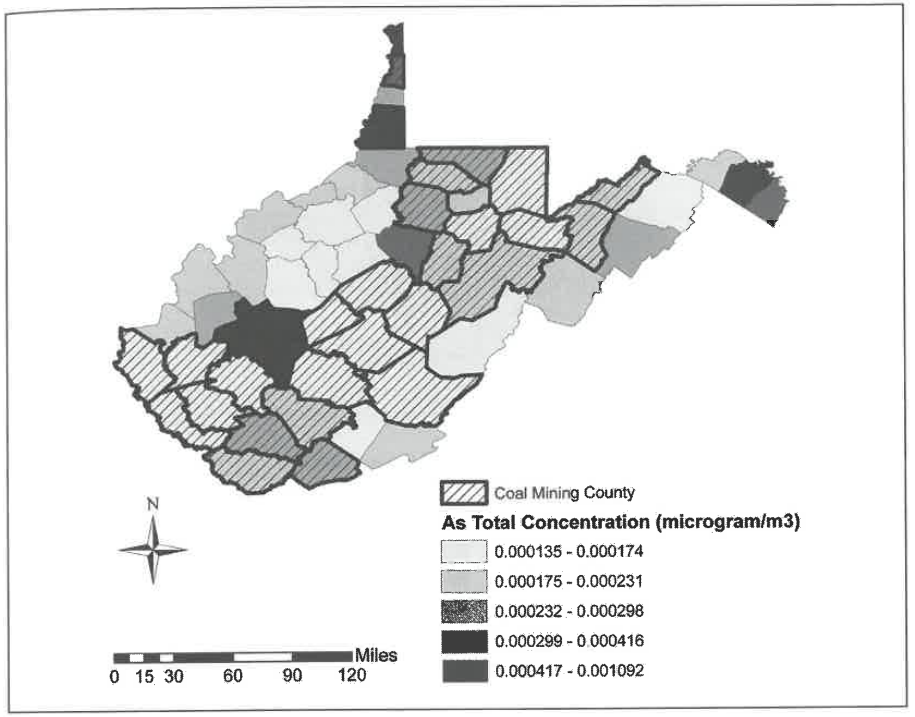

Figure 4. Arsenic concentrations by county in West Virginia (per 2005 NATA)

Environmental Protection Agency (CalEPA) has established a chronic inhalation reference level of 0.03 $\mu g/m^3$ for arsenic based on developmental effects in mice (http://www.epa.gov/ttn/atw/hlthef/arsenic.html) and 0.01 $\mu g/m^3$ for cadmium based on kidney and respiratory effects in humans (http://www.epa.gov/ttn/atw/hlthef/cadmium.html). Levels of these metals are modeled by NATA on a three year basis by both census tract and county, but it is important to note these levels are not coal mining specific; they represent numerous sources of both industrial as well as consumer-produced levels. The same can be said for all of the ambient air pollutants. As previously mentioned, all other sources of such emissions must be considered when evaluating coal and non-coal mining communities.

DISCUSSION

This study is an initial effort at descriptive demographics, coal production, and possible exposures for coal producing and non-coal producing counties in WV. However, it is limited by its descriptive and ecological nature. Associations between exposures and health outcomes have not been investigated. The information gathered and reported in this study should be used to inform further research into the health of coal mining communities in WV.

Subsequent research should include rates for specific health outcomes including Acute Myocardial Infarction (AMI), stroke, Chronic Obstructive Pulmonary Disease (COPD), and cancer. Additionally, the environmental exposures reported must be investigated for association with these health outcomes.

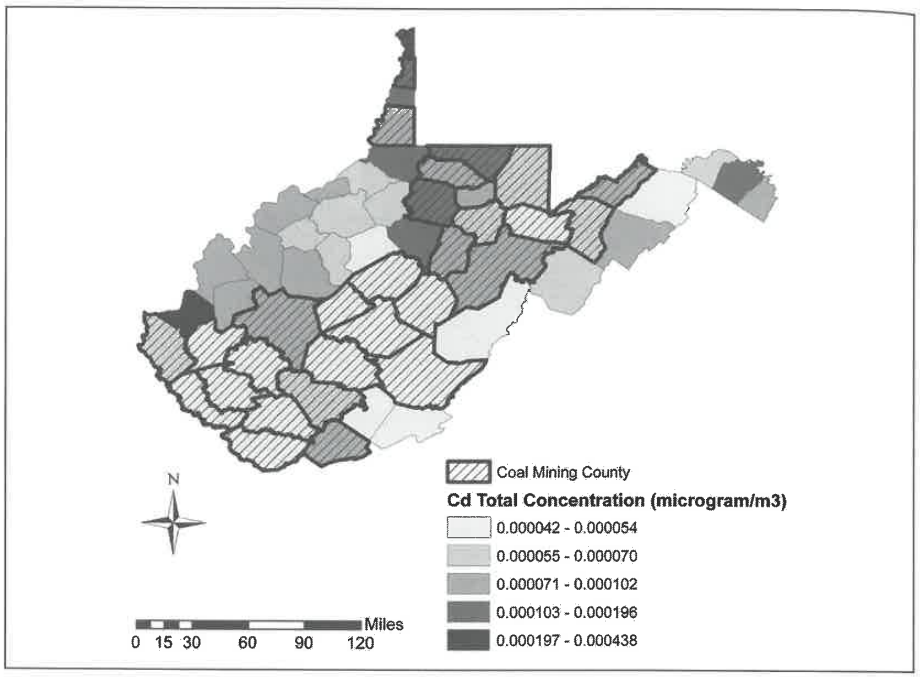

Figure 5. Cadmium concentrations by county in West Virginia (per 2005 NATA)

Crude rates of hospitalizations for circulatory and respiratory disease for one year (2007) have been presented here. Crude rates do not take into account the different age and sex distribution of different areas. Age is a primary determinant of health status; different age compositions between populations will influence morbidity rates (Lilienfeld 1976). Many health outcomes also differ by gender (Annandale 1990; Macintyre 1996). In order to compare rates of hospitalization in the counties of WV, age and sex adjusted rates must be calculated.

County level annual exposure estimates are broad characterizations and not specific to a personal residence. Environmental exposures actually vary by season, time of day, topography, and specific location within a county (Hoek 2008; Schwartz 1999). While it may not be possible at this time to achieve personal exposure estimates, smaller geographic areas such as zip code or census tract could be investigated to consider community level exposures.

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REFERENCES

Annandale, E., Hunt, K. 1990. Masculinity, femininity and sex: an exploration of their relative contribution to explaining gender differences in health. *Sociology of Health & Illness.* 12(1):24–46.

Beckett, W.S. 1991. Ozone, Air Pollution, and Respiratory Health. *The Yale Journal of Biology and Medicine.* 64:167–175.

Coggon, D., Taylor, A.N. 1998. Coal mining and chronic obstructive pulmonary disease: a review of the evidence. *Thorax.* 53:398–407.

Donoghue, A.M. 2004. Occupational health hazards in mining: and overview. *Occupational Medicine.* 54:283–289.

Environmental Protection Agency. National Ambient Air Quality Standards (NAAQS). http://www.epa.gov/air/criteria.html. (Accessed September 2012).

Environmental Protection Agency. Ozone (O_3) Standards–Table of Historical Ozone NAAQS http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_history.html. (Accessed September 2012).

Environmental Protection Agency. Fused Discrete Air Quality Surfaces. http://www.epa.gov/esd/land-sci/lcb/lcb_fdaqs_archive.html. (Accessed September 2012).

Environmental Protection Agency. National Air Toxics Assessment. http://www.epa.gov/ttn/atw/natamain/. (Accessed September 2012).

Environmental Protection Agency. Text Version: Mid-Atlantic Air Quality Monitors. http://www.epa.gov/reg3artd/airquality/r3monitors-tabular.htm. (Accessed September 2012).

Environmental Protection Agency. Technology Transfer Network Air Toxics Web Site. Arsenic Compounds. http://www.epa.gov/ttn/atw/hlthef/arsenic.html. (Accessed September 2012).

Environmental Protection Agency. Technology Transfer Network Air Toxics Web Site. Cadmium Compounds. http://www.epa.gov/ttn/atw/hlthef/cadmium.html. (Accessed September 2012).

Fernández-Navarro, P., García-Pérez, J., Ramis, R., Boldo, E., López-Abente, G. 2012. Proximity to mining industry and cancer mortality. *Science of the Total Environment.* 435–436:66–73.

Hendryx, M., Ahern, M.M., Nurkiewicz, T.R. 2007. Hospitalization Patterns Associated with Appalachian Coal Mining. *Journal of Toxicology and Environmental Health, Part A.* 70:2064–2070.

Hoek, G., Beelen, R., de Hoogh K., Vienneau, D., Gulliver, J., Fischer, P., Briggs, D. 2008. A review of land-use regression models to assess spatial variation of outdoor air pollution. *Atmospheric Environment.* 42:7561–7578.

Howel, D.H., Pless-Mulloli, T., Damell, R. 2001. Consultations of Children Living Near Open-Cast Coal Mines. *Environmental Health Perspectives.* 109(6):567–571.

Lilienfeld, A.M. 1976. Mortality Statistics. In *Foundations of Epidemiology.* Edited by Oxford University Press, Inc.

Macintyre, S., Hunt, K., Sweeting, H. 1996. Gender Differences in Health: Are Things Really as Simple as They Seem? *Soc. Sci. Med.* 42(4):617–624.

National Environmental Public Health Tracking Network Reporting Tool. http://ephtracking.cdc.gov/QueryPanel/EPHTNQuery/EPHTQuery.html. (Accessed September 2012).

Schwartz, J. 1999. Air Pollution and Hospital Admissions for Heart Disease in Eight U.S. Counties. *Epidemiology.* 10(1):14–22.

Talbott, E.O., Brink, L.L., Sharma, R.K., Marsh, G.M., Rager, J.R. *A Draft Report of the Comparison of NATA Air Lead Estimates with EPA Air Lead Monitoring Sites.* Annual Report to CDC in fulfillment of Contract 200-2010-374440. University of Pittsburgh Graduate School of Public Health, Pittsburgh, Pa 15261. Submitted September 29, 2011.

US Census Bureau. State & County Quick Facts: West Virginia. http://quickfacts.census.gov/qfd/states/54000.html. (Accessed September 2012).

West Virginia Office of Miners' Health Safety and Training. 2005 Coal Production by County http://www.wvminesafety.org/cnty2005.htm. (Accessed September 2012).