

Lung and Bronchus Cancer Deaths in Boone County, Wv Before and After Mountaintop Removal Mining

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Abstract

Coal has been mined from Boone County, WV for over 100 years. Mountaintop removal mining (MTR) has increased dramatically since the 1970's and may account for >30 per cent of West Virginia's coal. For people who live nearby, airborne particulate matter (PM) may present a health hazard. Our hypothesis was that deaths from lung and bronchus cancer (LBC) increased significantly in Boone County, WV between 1950-1969 and 2006-2012, the increase was not related to mining occupation and could not be completely accounted for by smoking cigarettes. Cause of death data were collected and stratified by gender, occupation and age and corrected for age. We compared LBC deaths pre- and post-MTR in (male) miners and non-miners, and (female) homemakers and non-homemakers. A statistically significant difference in LBC mortality for all ages and both genders between the periods 1950-1969 and 2006-2012 was found. The AADR for LBC was significantly higher in 10 counties with the most total acres under open permit in WV than in counties without MTR. The smoking-corrected OR for LBC in MTR-mined counties was 1.39 (95% C.I. 1.37, 1.41). There was no association between coal mining occupation and LBC AADR. However, homemakers had a significantly higher rate of LBC deaths during 2006-2012 than non-homemakers. Therefore a factor or factor(s) was present in the home environment that increased LBC deaths. Since MTR became prevalent in the 1980's and LBC has a latency period of 19-45 years, exposure to PM could have played a role, with synergy between smoking and environmental exposure.

Keywords: Appalachia; Health disparities; Lung and bronchus cancer; Respiratory disease; Coal mining; Particulate matter; Mountaintop removal mining

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Citation: Crosby L, Tatu C, Charles K. Lung and Bronchus Cancer Deaths in Boone County, Wv Before and After Mountaintop Removal Mining. J Rare Dis Diagn Ther. 2016, 2:1.

Received: February 01, 2016; **Accepted:** February 09, 2016; **Published:** February 15, 2016

Introduction

The Appalachian Region is defined as socio-economically disadvantaged [1] and many studies have sought to determine the causes for observed disparities in health [2-16]. Public health statistics (CDC/NIH) are available on a national, state- and county-wide basis however these statistics may not tell a complete story. Many individuals remain in their county of birth; most will remain West Virginia residents throughout their lives. In contrast, many areas of the U.S. experience frequent population shifts. Because of remaining in the county of birth, and a population which is not racially diverse, this homogeneous population is co-exposed to air, water and soil and ingest locally-grown foods throughout

their lives. Lifestyles have remained unchanged over generations and the environment of soaring mountains, thick forests, and crashing cataracts gives the impression of pristine beauty. In personal interviews with residents, most indicated a feeling of contentment and enjoyment of their surroundings and a strong attachment to their home, despite geographic isolation and poverty. But to this static existence have come ominous changes.

Although coal mining has been a major economic driver in West Virginia since shortly after the Civil War, underground coal mining began to decline in the late 1950's to early 1960's, and is still declining [17]. By contrast mountaintop removal mining (MTR), a less labour- intensive and more economical process, has increased drastically and in 2006 accounted for more than 30%

of West Virginia's coal production. MTR propels rock dust into the air and deposits rock overburden into valleys and streams altering topography and mobilizing material into the air, water and soil. Previous studies have examined the potential links between cancer, cardiovascular disease, birth defects, dental health, etc., as discussed below, and living near MTR. However, to date no study has systematically examined the difference in LBC deaths from a period before, and one several decades after, MTR in an intensively-MTR mined county, or the differences between male and female occupations. We hypothesized that there is a significant difference between numbers of deaths from LBC from a period before MTR introduction compared to a period several decades after, and that this difference would not be affected by occupation. We further hypothesized that not all of the increase in LBC mortality in Boone County between these two periods could be accounted for by smoking, an important consideration since it is estimated that 80% of LBC is attributable to cigarette smoking.

Method

Power calculations

Power calculations were carried out in order to determine the number of data points that should be collected. Calculations are based on formulas for the 1-Sample Z Test. The population of Boone Co. in 1960 was 28,764. Based on a 95% C.I., the recommended sample size was 380 [18]. We examined 530 death certificates. In 2005 and 2010 the population was 25,535 and 24,629, respectively, requiring a sample size of 379 (either year) at the 95% confidence level. We examined 754 death certificates. The number of death certificates examined was adequate to detect true differences at the power level of $\alpha=0.05$. For each of the 9 zip codes within Boone County that were examined, the sample size requirement was not met, due to the small population sizes. Instead the margin of error was calculated for each zip code and is given as ' \pm margin of error'. Margin of error (E) refers to $E=z_{\alpha/2} (\delta/\sqrt{n})$ where $z_{\alpha/2}$ is a critical value (1.96), δ =standard deviation, and n =sample size.

Data collection

Death certificate data were transcribed for the years 1960-1963 (all of Boone County) and nine zip codes within Boone County: 25081, 25130, 25181, 25193, 25204, 25205, 25206, 25208, and 25209, for the years 2006-2012. Zip codes were not yet used in 1960-1963. The 9 zip codes were either towns where we previously carried out environmental sampling or included the county seat, Madison. Death certificates from 1960-1963 were available online from The West Virginia Division of Culture and History [19]. Cause of death was coded using WHO ICD-10: Version 2010. The data collected included birth and death date, cause of death (primary, secondary and underlying), gender, race, occupation, location and number of years of education.

CDC/NIH NHANES data for Boone County, WV, and US LBC deaths was obtained from seer cancer [20] and for the Standard Million to perform age adjustment for the AADR. US census data [21] was obtained for actual population numbers in Boone County, WV, and the US. AADR data for 2005-2009 for Boone County was

from University of Wisconsin [22] and Public Health Service [23]. Smoking prevalence for Boone County was obtained from West Virginia Department of Health and Human Resources et al. [24].

Data analysis

Comparisons were made for lung and bronchus cancer deaths over time using National Cancer Institute [25] National Institutes of Health and U.S. Dept. of Health and Human Services [26], State of West Virginia et al. [27], State of West Virginia et al. [28].

Age-adjusted death rates were calculated using the NCI SEER Program method for individual zip codes listed above (2006-2012). The population of each zip code was obtained, stratified by age, from 2000 census data. 2000 Census data was used because the deaths occurred during 2006-2012. The age-categorized populations and AADR for LBC of Boone County, West Virginia, and the U.S. (1950-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004, 2005, 2006-2010, 2007-2011), were obtained from Census data and Vital Statistics (ibid). 1950-1969 data ranges were included because ranges for LBC alone (official data collected during that period grouped lung, bronchus, pleura and tracheal cancers together) were not available for the years 1960-1964. Confidence limits were calculated and the chi-square statistic was computed for comparisons of the different times using the data collected from death certificates in 1960-1963 and 2006-2012 to determine true differences between before and after MTR.

The top ten counties for mountaintop mining removal activity in WV were identified by the number of acres under open permit using Government Accountability Office 2009 [29], Ahern et al. [3] and the values averaged. The ten lowest MTR counties (counties that had no reported MTR) were also identified (same sources) and the values averaged. AADR data for 2005-2009 for these counties in WV were from University of Wisconsin Population Health Institute 2014 [22] and Public Health Service et al. [23]. Statistics were calculated using Excel software and a correction for smoking was carried out using the Cochran-Mantel-Haenszel method. Briefly, using 2 x 2 tables for smokers and non-smokers in WV, with categories of LBC present/absent and MTR present/absent, the odds ratio (OR) and confidence limits were calculated.

Results

Using official statistics, **Figure 1** [30-32] and **Table 1** show that comparing the period 1950-1969 to the period 2006-2012, the Boone County LBC AADR has increased significantly from 39 to 95. Using death certificates data, the chi-squared statistic revealed that the period 1960-1963 differed from 2006-2012 significantly at $\alpha=0.001$ or lower level. The all-site cancer death AADR per 100,000 persons/year has also increased substantially since 1960-1963 (**Table 1**).

Although individual state data are not available for the 1960's, it is known that smoking prevalence peaked in the US in the mid-1960's at 42% for both genders and all races (Centres for Disease Control and Prevention [33]) and nationwide has decreased by half since then. In West Virginia, smoking prevalence has been relatively static since 1980 at 30% (State of West Virginia et al. [27], State of West Virginia et al. [28]). Today 26% of West Virginians

smoke cigarettes, however for MTR counties no change occurred during the period 1993-2003, the decade just prior to the period under study (data not shown). In Boone County, smoking prevalence is 39% for all persons over the age of 12 [34] and 30% for adults. We asked whether deaths not due to smoking could account for some of the LBC deaths and if so, how many. Smoking cigarettes is known to cause approximately 80% of all LBC deaths [35]; therefore smoking is a confounder for effects due to MTR. The total number of LBC deaths for the sampled zip codes within Boone County

was 69 (2006-2012). Using known percentages of smoking-related deaths [35] we calculated the number of LBC deaths that were likely attributable to non-smoking causes to be 14, and to smoking-related causes to be 55. In addition, 126 other, non-LBC deaths during the same period were attributable to smoking-related causes.

There were significantly more LBC deaths in the top ten MTR counties of WV ($p < 0.001$) than in 10 counties without mining by this method, as shown in **Figure 2**. After correction using the Cochrane-Mantel-Haenszel method which takes into account confounding by smoking, the OR for LBC death in a MTR county (10 counties averaged) was 1.39 (95% C.I. 1.37, 1.41) compared with a non-MTR county.

Nevertheless, there is a concern that a surge in LBC deaths due to smoking in earlier years might have affected these results. We therefore asked whether a maximal rate of LBC deaths (due to peak smoking years in the mid-1960's) occurred before 2006-12. Lung & bronchus cancer has a minimum latency of from 9 to 19 years [36] and a maximum of approximately 45 years [37], therefore, peak lung & bronchus cancer deaths linked to smoking in the early 60's should have occurred by 2000 [38], however these data show that lung & bronchus cancer rates continued to increase among all persons in Boone County (**Figure 1; Tables 1 and 2**) from 1980 through 2012. The official rate through 2011 was 95.0 per 100,000 persons (79.8, 112.5: 95% C.I.). By contrast, Jefferson County WV, a county where there is no MTR recently had a rate of 62.1 deaths per 100,000 persons (52.7, 72.6: 95% C.I.).

In Boone Co. during 2006-2012 (these data) the AADR for LBC was 50.7 for men and 40.1 deaths for women per 100,000 persons (average annualized); combined it was therefore 90.8, taking into account the differing proportions of males and females in the U.S. population and not calculated using local population distributions. 73% of the women included in this total were homemakers (all persons listed as 'homemakers' were female). None were employed in construction, mining or heavy industrial occupations (one was listed as 'hanger maker'). 76% of the men



Figure 1 Age-adjusted deaths from lung and bronchus cancer per 100,000 people. Per official statistics, there was a marked difference between the periods 1950-1969 and 2006-2010 in Boone County (average annualized) and between 1980-1984 (approximate date of the introduction of MTR mining technology) and 2006-2010 (when MTR had been in use for over 20 years, and beyond the minimum latency period for LBC). For WV and the US, by contrast, the LBC AADR initially increased slightly, and then became stable to slightly decreasing. During 2007-2011, the rate of death from LBC in Boone County decreased compared with 2005-2010, however it remains twice as high as the pre-1980 rate.

Table 1 Annual age-adjusted lung & bronchus cancer death rate in Boone Co., WV, and U.S. for representative years before and after MTR.

	Lung & Bronchus Cancer (95% C.I.)	All Cancers (95% C.I.)
Boone County (1950-1969)	39.5 (22.8, 56.2)	124.5 (114.7, 134.3)
West Virginia (1950-1969)	32.6 (30.8, 34.4)	139.8 (138.6, 141.0)
U.S. (1950-1969)	29.3 (29.2, 29.5)	150.1 (150.0, 150.2)
Boone County (1960-1963, these data)	3 (2.5, 3.5)	30.4 (28.8, 32.0)
Boone County (1960-1964)*	21.6 (23.9-38.5)	133.4 (112.9, 153.9)
West Virginia (1960-1964)*	22.1 (21.2-23.1)	141.7 (139.3, 144.1)
U.S. (1960-1964)*	22.2 (22.1-22.3)	149.5 (149.2, 149.7)
Boone County (1970-1974)	31.9 (22.2, 41.6)	138.3 (118.1, 158.6)
West Virginia (1970-1974)	37.6 (36.4, 38.8)	159.5 (157.0, 162.1)
U.S. (1970-1974)	34.1 (34.0, 34.2)	160.0 (159.8, 160.3)
Boone County (2000-2004)	79.9 (66.4, 93.5)	191.9 (171.0, 212.9)
West Virginia (2000-2004)	69.6 (68.0, 71.1)	148.1 (146.1, 150.2)
U.S. (2000-2004)	54.7 (54.6, 54.8)	131.0 (130.3, 130.7)
Boone County (2007-2011)	95.0 (79.8, 112.5)	250.8 (225.3, 278.6)
West Virginia (2007-2011)	63.8 (62.3, 65.2)	200.3 (197.7, 202.9)
U.S. (2007-2011)	47.4 (47.2, 47.7)	173.8 (173.6, 174.0)

For the Boone Co. data analyzed during 2006-2012, the 2000 population was used to determine the crude rate.

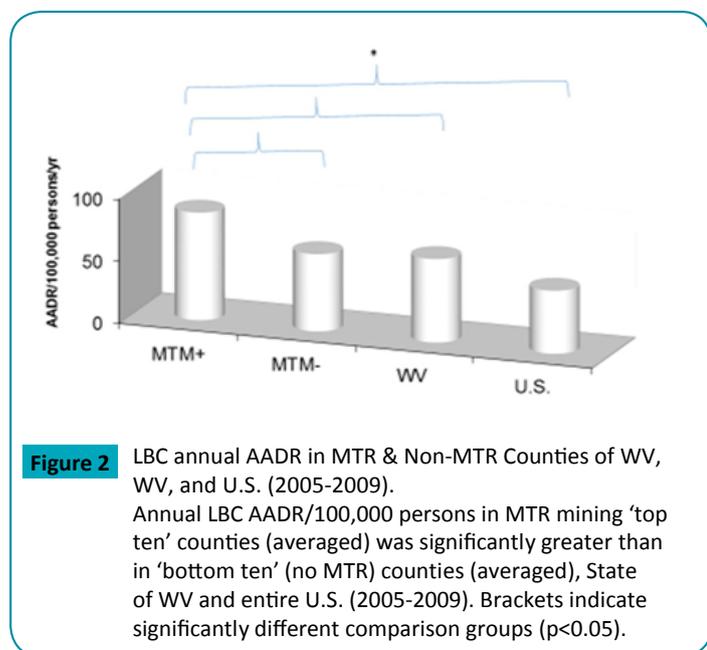
*Includes lung, trachea, bronchus & pleura because data for lung & bronchus only was not collected during these years.

Table 2 AADR's for cancer subtypes in 9 Sub-County zip codes compared with Boone County.

Town and Zip code	2006-2012 AADR Lung & bronchus	±margin of error	2006-2012 AADR Cancer All Sites	± margin of error
Foster, WV 25081	47	(42.3, 51.7)	216.8	(195.3, 238.3)
Madison, WV 25130	58.6	(55.6, 61.5)	174.5	(165.8, 183.3)
Seth-Prenter, WV 25181	72.4	(67.6, 77.1)	201.2	(187.9, 214.5)
Sylvester, WV 25193	56.5	(49.0, 64.0)	344.4	(298.5, 390.2)
Twilight/Bandytown/Lindytown, WV 25204	176.6	(145.0, 208.1)	176.6	(145.0, 208.1)
Uneeda, WV 25205	129.4	(106.9, 151.9)	272.3	(224.9, 319.7)
Van, WV 25206	77.6	(69.3, 85.8)	134.4	(120.2, 148.7)
Wharton, WV 25208	85	(76.6, 93.3)	330.9	(298.5, 363.3)
Whitesville, WV 25209	75.9	(69.5, 82.2)	199.5	(182.7, 216.3)
9 zip code average	86.5	95% C.I.**, ***	227.8	95% C.I.**, ***
Boone County (all zips, 2007-2011)	95	(79.8, 112.5)	250.8	(225.3, 278.6)

** Significantly higher than WV

*** Significantly higher than U.S.



included in this total were employed in heavy industry such as coal mining, lumber, automotive, trucking, and railroads. Females had 10.6 fewer deaths per 100,000 than males.

Because this gap was smaller than anticipated considering that most women were not employed outside the home, we decided to look in depth at the differences between men and women and asked whether their profession had any effect on their relative risk for LBC mortality (2006-2012 death certificates data). There was no significant difference between LBC mortality in men (total of 399) who worked in mining (20 of 189) vs. non-mining (23 of 187) professions (p=NS). However for homemakers (total of 355) there was a significantly increased (p<0.03) rate of LBC deaths (19 of 195) compared with non-homemakers (7 of 160). A Chi Squared test for independence between occupation and cause of death verified these results for both genders (X²=3.84, d.f.=1).

Discussion

Lung & bronchus cancer death rates have increased significantly

since the introduction of MTR in Boone County (all genders, ages, corrected for age). All site cancer death rates have likewise increased significantly over time. There were significantly more deaths from LBC in MTR counties than in non-MTR counties of WV (OR=1.39). The Boone County deaths could not be completely accounted for by smoking cigarettes (14 deaths occurred during 2006-2012 in 9 zip codes sampled, from non-smoking-related causes). Occupation had no effect on deaths from LBC for males, however, for females; homemakers had a significantly elevated risk of death than their working counterparts.

MTR in West Virginia began in the early 1970's, with fewer than 20 permits issued. After 1977 when the Surface Mining and Recovery Act (SMCRA) authorized MTR, it began to be more prevalent and has continued to expand. As of 2013, WV MTR has grown to approximately 352,000 acres [39] and nationwide, about 1.2 million acres. Because of this increase, exposure to particulates into the air could be a factor in increases in LBC deaths. Given the latency period of LBC, any smoking-related bolus increase should have been observed already, as smoking rates peaked in 1960-1965 across the U.S. and are estimated to have decreased or remained stagnant in Boone Co., since then. In fact, nationwide, LBC cancer deaths peaked in 1985-1990 for men and 1995-2000 for women, after which they have declined (both sexes). For Boone County, after correcting for smoking, there was still a significant increase in LBC mortality beginning with 1980-1984, which continued to increase through 2012, almost doubling from 54 to 91, 95, or 127 LBC deaths per 100,000 persons per year, depending on data source.

Based on known values for the percentage of lung and bronchus cancers attributable to smoking, and the actual number of LBC deaths in 9 zip codes within Boone County (2006-2012), we have estimated that a total of 14 deaths occurred from causes other than smoking. The LBC AADR increased by 50 to approximately 100 per 100,000 people per year, since MTR began. Since Boone County has a population of approximately 25,000 people, the annual increase in human LBC deaths after MTR is estimated to be about 12.5, or, for 2006-12, 98 deaths. The actual number observed was 10.22 per year, or 71.4 in 7 years, only in the 9 zip codes for which we collected data. 27 unaccounted LBC deaths therefore likely occurred in the remaining un-sampled portions of Boone County. To re-iterate, the total increase in LBC deaths

as compared with before MTR, during 2006-2012 in Boone Co., is estimated to be 98.

The work of others has explored the correlation between residential proximity to MTR and heart, respiratory and kidney disease [6], poverty and health disparities [11], cancer hospitalizations [15, 40], quality of life [41, 42], tooth loss [14], birth defects [3], chronic cardiovascular disease [4], cancer mortality [2], coronary heart disease and heart attack morbidity [8], and other health factors [4, 5, 16, 40]. All of the studies concluded that living in a MTR area is correlated with negative health outcomes. Relatively few studies have examined physical factors in the environment; several studies of note are Beelen R [43], Kurth [44], Kurth L [45], Kurth et al. [46] and Knuckles et al. [37]. There are no published studies of the health status of the residents of MTR areas excepting self-assessment questionnaires [15].

The prevalence of smoking in Boone County, a high mining activity county, continues to be shockingly high and has not altered in decades. Indeed it is among the highest in WV and is significantly higher than the rest of the US. The physical effects of nicotine have been shown to exert a calming effect on smokers [37]. According to Balfour et al. [47], "Nicotine is a powerful chemical that offers smokers pleasure and reward, focuses attention, suppresses hunger, calms stress, elevates mood, and relieves nicotine withdrawal." The areas where MTR takes place usually contain the following: underground, surface, and/or mountaintop removal mines, coal processing plants (with emissions and odors) and coal slurry ponds (with increased noise, diesel fuel emissions, dust, odors and truck traffic), explosions with associated dust and noise, coal smoke, petroleum odors, coal trains and coal-carrying semi-trucks (with increased diesel fuel particulates, odor, noise, and road congestion), and movement of heavy earth-moving equipment such as drag lines (with increased road traffic, odors and emissions). According to Cordial, et al. [48] and references therein, living in MTR environments appears to cause significant mental health effects. Cigarette smoking may be part of a coping strategy for living in stressful environments.

According to Doll & Peto [49], lung cancer can be attributed 90% to active smoking, 10-15% to occupational exposure, 10% to radon, and 1-2% to outdoor air pollution. An uncertain amount is attributable to diet, and possibly 15 to 20% to heredity. (Percentages sum to >100 because risk factors overlap.) More recently, the ESCAPE Project estimated air pollution accounts for 7 to 19% of all cancer deaths [50]. Dockery et al. [51] analysed data from six U.S. cities in 1993 and found approximately 1-2% of LBC was attributable to outdoor air pollution. Pope et al. [52] found the adjusted risk for lung cancer mortality in cities with the highest concentration of fine particles was 1.4 times higher than in the least polluted city (95% CI: 0.8, 2.4), and tested residences in high sulphate concentration areas and found an increased risk for lung cancer (adjusted RR 1.4, 95% C.I.: 1.1, 1.7), but fine particulate matter was not associated with increased lung cancer risk in that study. A follow-up collaboration of the same group found the risk for lung cancer increased 13% per 100 µg/m³ increase in PM₁₀ [53] and the response was linear with no safe lower threshold. Kurth et al. (Kurth [43, 44]; Kurth et al. [45]) found increases in particulate matter in MTR areas compared with

non-MTR areas of south western WV, which were correlated with negative consequences to human health. The work of Pope, et al. compares well with our results of OR = 1.39 for the ratio of risk of death due to LBC in MTR counties to that in non-MTR counties, suggesting that similar risks for air particulates are operating.

Turner et al. [54] carried out a large prospective cohort study of 1.2 million participants recruited in 1982 and found a relative excess risk of lung cancer mortality due to the interaction of cigarette smoking and exposure to fine particulate matter (PM_{2.5}) of 2.19 (95% CI, -0.1, 4.93) and the attributable portion due to interaction was 0.14 (95% CI, 0.00, 0.25). These results were greater than that expected based on adding the risks of cigarette smoking and fine particulate matter exposure together. Translating to Boone County, 105 persons may have died due to synergistic particulate matter and cigarette smoke effects (from any cause, not just LBC) during the seven year period 2006-2012. Taken together with the work of Kurth et al. regarding ambient levels of PM in MTR areas and the known mining activity and tobacco use, it seems reasonable to conclude that synergistic effects from particulate matter and smoking could have contributed to increased mortality in recent years.

Increases in LBC and all cancer AADRs occurred in both genders. We did not examine differences in race because Boone County is 99% white. Because the gap between AADR for LBC in men and women was small given most women did not work outside the home, it is possible that some other factor, e.g. environmental exposures at the place of residence contributed to female risk. We found no difference in LBC deaths for men regardless of mining or non-mining occupation while for homemakers (all female, there was a significant increase in LBC mortality compared with non-homemakers, during 2006-2012.

Conclusion

We found that lung & bronchus cancer death rates have increased significantly since the introduction of MTR in Boone County. Because of the small size of the sub-county data portion of the study, conclusions from those data are tentative and bear further study. Numbers for the individual zip codes within Boone County have no statistical significance due to the small sample size and incompleteness (the entire county was not sampled), and are only qualitative. However, data included from official sources are unequivocal and show that significant increases in LBC have occurred over the time period examined. Other changes have occurred in Boone County since the earlier period (1950-1970) that may have an effect on the overall composition of the population and its susceptibility to diseases and death. Between 1999 and 2006 the average lifespan decreased in Boone Co. by 3.1 years [55] and lifespan is now in the lowest 10% of the US. Many types of cancer have appeared in 2006-2012 that were not observed in 1960-1963. Infant mortality has dropped from approximately 8% to less than 1% (these data, data not shown). Drug overdose emerged as an epidemic cause of death during 2006-2012 (these data, data not shown). Changes in diagnostic criteria or medical diagnosis and treatment may have affected the

stated cause of death or the longevity of individuals with certain conditions. Other diseases may not have been recognized, or may have been too rare to be observed in data sets of this size. The population in Boone County has decreased over time. Other sources of air pollution and routes of contaminant exposure may have contributed to these increases but if so their nature and source(s) are not known. In the absence of other sources of exposure, the data suggest that the introduction of mountaintop removal mining could have affected mortality in Boone Co., WV.

Support

Financial support was provided by US Geological Survey, Energy Resources Program, to the authors during the period of this work.

Acknowledgement

We would like to thank Bill Orem, Eastern Energy Resources Science Centre, USGS. We would like to thank the people of West Virginia for their welcoming hospitality and bravery.

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