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Review article

The public health impacts of surface coal mining

Michael Hendryx

Department of Applied Health Science, School of Public Health, Indiana University, Bloomington, IN 47405, USA

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ABSTRACT

The current paper reviews published evidence on the public health impacts of surface coal mining. Particular attention is paid to recent evidence for a form of surface mining practiced in the United States, namely mountaintop removal mining. Studies from other parts of the world are also briefly described. Evidence is presented that documents epidemiological disease patterns for populations living in proximity to surface mining. Environmental evidence has shown that surface waters and biota are harmed by mountaintop removal, while other environmental studies have shown water and air pollution exist in residential areas close to mining. Studies that are able to directly link environmental exposure, dose, and biological impact are urgently needed. Although direct mechanistic links are not well understood, the weight of the evidence reinforces previous science-based calls to discontinue mountaintop removal mining due to its environmental and public health risks.

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1. Introduction

> *"Dr. Diane Shafer, a busy orthopedic surgeon in Williamson, the Mingo County [WV] seat, noticed that a surprising number of her patients in their fifties were afflicted with early-onset dementia. In addition, she was hearing more and more complaints about kidney stones, thyroid problems, and gastrointestinal problems such as bellyaches and diarrhea. Incidents of cancer and birth defects seemed to be rising, too. She had no formal studies to back her up, but . . . she knew that many people who lived in the hills beyond the reach of the municipal water supply had problems with their water."* Jeff Goodell, Big Coal, pp. 40–41.

Jeff Goodell, a highly regarded journalist, published the book Big Coal in 2006 (Goodell, 2006). The book details the environmental and economic costs of America's reliance on coal as an energy source. He also describes the public health harm caused by burning coal in power plants, for which there is considerable research evidence. Scattered here and there in the book's pages are impressions of local mining community residents, such as Dr. Shafer, that the *mining* of coal, not just its burning, causes public health problems as well. But research evidence that could support or refute these impressions was lacking.

At that time the research evidence that was available on coal mining's health impacts seemed to be limited to studies on occupational exposure, and to a few studies conducted in Great Britain on mining's possible larger public health impacts. Regarding occupational exposures, underground coal mining is known to increase risk of pneumoconiosis, chronic obstructive pulmonary disease, lung cancer and perhaps other illnesses (Castranova and Vallyathan, 2000; Coggon and Taylor, 1998; Graber et al., 2014; Laney et al., 2012; Scott et al., 2004). These occupational diseases are related to inhalation of coal and rock

E-mail address: hendryx@indiana.edu (M. Hendryx).

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dust and other mining related chemicals, that is, to air quality problems. The studies in Great Britain also focused on air quality, and examined possible respiratory problems for people, usually children, who lived near open-cast or surface coal mining sites (Brabin et al., 1994; Temple and Sykes, 1992). Yet, as suggested above by Dr. Shafer's concern, the original focus in examining possible public health consequences of surface mining in the United States emphasized water quality issues.

The issue is complicated by the fact that mining populations, especially in Appalachia in the eastern United States, experience high levels of poverty, and often engage in poor health behavior reflected by high smoking and obesity rates. It is relatively easy to show that mining populations have poor public health outcomes, but more challenging to identify whether or not environmental conditions caused by mining contribute to those outcomes over and above socioeconomic and behavioral risks. The current paper reviews the literature on the public health consequences of coal mining, focusing especially but not exclusively on evidence since 2006 and evidence from mining in Appalachia. Appalachia is a focus because of the advent of mountaintop removal mining, a form of large scale surface coal mining that has major environmental impacts, occurs in close connection to human settlements and has been most clearly identified as a public health concern by local residents. The paper will review the evidence base and present questions that direct the next research and policy steps that should be undertaken to understand, and where indicated to reduce, the negative environmental impacts of coal mining on public health. Before beginning to review the health literature, the paper provides a brief description of mountaintop removal mining and its ecological impacts.

2. Mountaintop removal mining

Mountaintop removal mining (MTR) is an aggressive form of surface coal mining that occurs on ridges and mountaintops in steep terrain. The depth and size of the coal seams and the topography of the land sometimes make other forms of mining impractical. It occurs in areas of four states in Central Appalachia including Kentucky, West Virginia, Virginia, and Tennessee, and is distributed over an area approximately equal in size to the states of Vermont and New Hampshire combined. About three million people live in counties where mountaintop removal is practiced. Most residents in these areas live in valley bottoms along rivers and streams or in other relatively small, flat areas beneath the mountains.

As early as 1997, mountaintop removal was recognized as a growing hazard and was characterized as "strip mining on steroids" (Galuszka, 1997). As the name implies, the practice involves the removal of up to hundreds of feet of rock and soil to reach coal seams. Before beginning this removal, forests are clear cut and often burned. The rock and soil overburden is loosened by explosives, scooped by draglines and dropped into large trucks, which typically cart the overburden short distances to the nearest valleys where it is dumped over the side. The overburden permanently buries headwater streams and eventually entire valleys may be filled. The newly uncovered rock and soil are exposed to oxygen and rain and begin to leach long-sequestered minerals, metals and other chemicals. The water that emerges from the base of the valley fills is contaminated with these chemicals.

Important work on the water chemistry impacts of mountaintop removal mining has been conducted by several groups of researchers. This research shows that effluents from valley fills typically contain high salinity, selenium, and sulfate concentrations (Vengosh et al., 2013). Sulfates can increase levels of toxic hydrogen sulfide (Palmer et al., 2010). Increases in pH, electrical conductivity and total dissolved solids are also observed as a consequence of MTR (Palmer et al., 2010). Effluents from valley fills continue for years after active mining at a site has ceased, and effects accumulate as streams pass through mining sites and receive water from multiple mines (Lindberg et al., 2011).

The impact of mining on surface waters raises questions of impacts on biota in those waters. Mining disturbance causes a decline in stream biodiversity with consequences that extend well beyond the limits of the mining permits (Bernhardt et al., 2012; Hitt and Hendryx, 2010; Pond et al., 2008). Palmer et al. (2010) report declines in numbers of invertebrate genera as sulfate concentrations from mountaintop mining increase. The increases in selenium noted above have been linked to teratogenic deformities in fish and reproductive failure in fish and in birds that consume the fish (Lemly, 2007).

3. Early health studies

Research conducted prior to Mr. Goodell's publication includes a large body of evidence on the occupational health risks of coal mining. A few of those studies were cited above. The current review will not attempt to summarize that literature, but rather points to it only to illustrate that harmful consequences of exposure to mining activity have long been known. Miners are exposed to diesel particulates, dust, chemicals, fuels and elemental toxicants (Scott et al., 2004). Of course, exposures faced by underground miners working in confined spaces do not mean that there are harmful exposures faced by community populations. But we also cannot assume that community environments are benign if they are located in proximity to mining activity.

The first studies on public health effects from coal mining appear to have been conducted in Great Britain. Temple and Sykes (1992) published perhaps the earliest account in the scientific literature. They showed substantial increases in medical visits for asthma in conjunction with the opening of a surface mine. Brabin et al. (1994) reported significantly higher occurrence of respiratory symptoms among children exposed to coal dust, and a few years later, Pless-Mulloli et al. (2000) reported weak but significant associations between surface coal mining and children's respiratory health (Howel et al., 2001; Pless-Mulloli et al., 2000). Pless-Mulloli in other studies, however, has reported no relationship between surface coal mining and children's respiratory health (Moffatt and Pless-Mulloli 2003; Pless-Mulloli et al., 2001).

An additional, relatively early study of coal mining effects was reported from Turkey. Yapici et al. (2006) measured blood levels of cadmium and lead in children living near coal mining activity, and found levels substantially higher than in other urbanized areas of Turkey, and in the case of cadmium the levels exceeded World Health Organization risk limits. They speculated that children may have ingested contaminated dust and soil secondary to air deposition. However, they were not able to ascertain whether the exposures were due to mining or perhaps resulted from other industrial activities in the area.

It is interesting to note that in all of these earlier health studies the focus was on possible effects from mining-related air pollution exposures. Possible risks from water pollution it seems had not been investigated. As mountaintop removal emerged as a major mining technique in the mid-1990s in Appalachia, concerns for its ecological impacts revolved primarily around water. The focus on water seemed to be reinforced by early public concerns of contaminated private well supplies. But the use of explosives and heavy diesel equipment, and the necessity of removing overburden to reach coal seams all suggest possible air pollution effects, and both air and water exposure routes should be considered.