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Review article

Systematic review of community health impacts of mountaintop removal mining☆

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ABSTRACT

Background: The objective of this evaluation is to understand the human health impacts of mountaintop removal (MTR) mining, the major method of coal mining in and around Central Appalachia. MTR mining impacts the air, water, and soil and raises concerns about potential adverse health effects in neighboring communities; exposures associated with MTR mining include particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), metals, hydrogen sulfide, and other recognized harmful substances.

Methods: A systematic review was conducted of published studies of MTR mining and community health, occupational studies of MTR mining, and any available animal and in vitro experimental studies investigating the effects of exposures to MTR-mining-related chemical mixtures. Six databases (Embase, PsycINFO, PubMed, Scopus, Toxline, and Web of Science) were searched with customized terms, and no restrictions on publication year or language, through October 27, 2016. The eligibility criteria included all human population studies and animal models of human health, direct and indirect measures of MTR-mining exposure, any health-related effect or change in physiological response, and any study design type. Risk of bias was assessed for observational and experimental studies using an approach developed by the National Toxicology Program (NTP) Office of Health Assessment and Translation (OHAT). To provide context for these health effects, a summary of the exposure literature is included that focuses on describing findings for outdoor air, indoor air, and drinking water.

Results: From a literature search capturing 3088 studies, 33 human studies (29 community, four occupational), four experimental studies (two in rat, one in vitro and in mice, one in *C. elegans*), and 58 MTR mining exposure studies were identified. A number of health findings were reported in observational human studies, including cardiopulmonary effects, mortality, and birth defects. However, concerns for risk of bias were identified, especially with respect to exposure characterization, accounting for confounding variables (such as socioeconomic status), and methods used to assess health outcomes. Typically, exposure was assessed by proximity of residence or hospital to coal mining or production level at the county level. In addition, assessing the consistency of findings was challenging because separate publications likely included overlapping case and comparison groups. For example, 11 studies of mortality were conducted with most reporting higher rates associated with coal mining, but many of these relied on the same national datasets and were unable to consider individual-level contributors to mortality such as poor socioeconomic status or smoking. Two studies of adult rats reported impaired microvascular and cardiac mitochondrial function after intratracheal exposure to PM from MTR-mining sites. Exposures associated with MTR mining included reports of PM levels that sometimes exceeded Environmental Protection Agency (EPA) standards; higher levels of dust, trace metals, hydrogen sulfide gas; and

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a report of increased public drinking water violations.
Discussion: This systematic review could not reach conclusions on community health effects of MTR mining because of the strong potential for bias in the current body of human literature. Improved characterization of exposures by future community health studies and further study of the effects of MTR mining chemical mixtures in experimental models will be critical to determining health risks of MTR mining to communities. Without such work, uncertainty will remain regarding the impact of these practices on the health of the people who breathe the air and drink the water affected by MTR mining.

1. Introduction

Since its introduction in the 1960s, mountaintop removal (MTR) mining has become a major method of coal mining in and around Central Appalachia (including parts of Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia) because it is typically faster, cheaper, and less labor intensive than underground mining (Holzman, 2011). This mining method involves clearing the area of trees and topsoil and using explosives to blast apart the mountain rock to access coal seams (Palmer et al., 2010). The excess rock (i.e., mine spoil) is often pushed into adjacent valleys (i.e., valley fill). The air, water, and soil in the surrounding area are impacted by these mining practices and contamination due to MTR mining has the potential to adversely impact human health in the surrounding community (Acton et al., 2011; Palmer et al., 2010; Simmons et al., 2008). Exposures associated with MTR mining include PM, PAHs, metals, and other potentially harmful substances (Palmer et al., 2010).

The overall objective of this evaluation is to understand the human health impacts of MTR mining by conducting a systematic review of published studies of MTR mining and community health, occupational studies of MTR mining, and any available animal and in vitro experimental studies investigating the effects of exposures to MTR-mining-related chemical mixtures. The Population, Exposure, Comparator, and Outcome (PECO) Statement includes all human population studies and animal models of human health, direct and indirect measures of MTR-mining exposure, studies which provided vehicle-only controls in experimental studies, any health-related effect or change in physiological response, and any study design type. To provide context for these health effects by characterizing components of these MTR-mining-related mixtures, a summary of the exposure literature is included as well. This analysis will identify important areas of future research needs and provide recommendations to strengthen the design and conduct of future studies assessing the health effects of MTR mining.

2. Methods

The detailed protocol for conducting this systematic review was drafted in consultation with experts in the field, registered in PROSPERO (an international prospective register of systematic reviews, registration number PROSPERO 2016:CRD42016037192, http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016037192), and posted publicly on the NTP website (http://ntp.niehs.nih.gov/go/780611) on April 3, 2016 (Boyles et al., 2016). A revised protocol with updated exclusion criteria was posted on July 27, 2016 prior to initiating data extraction. The protocol includes: review aims, problem formulation, literature search strategy, detailed inclusion/exclusion criteria, data extraction process, individual study quality assessment method (i.e., risk of bias), and strategy for evidence synthesis and reaching hazard conclusions.

The literature search strategy included 6 databases (Embase, PsycINFO, PubMed, Scopus, Toxline, and Web of Science) with customized terms and no restrictions on publication year or language (see Appendix 1 of protocol). This review includes all references identified through October 27, 2016. Hand searching for additional relevant references was conducted of the reference lists of relevant reviews and commentaries identified during the initial search and the reference lists of studies included after the full text review. A Request for Information on "Mountaintop removal mining (health impacts on surrounding communities)" including published, ongoing, or planned studies related to evaluating adverse health outcomes was published in the Federal Register on October 7, 2015 (https://ntp.niehs.nih.gov/ntp/presssctr/frn/2015/80frn194ntp20151007_htm.pdf) to try to identify additional references.

Title/abstract and full text screening was conducted by independent screeners (RBB, SBG, and SM) with two screeners per article. Conflicts were resolved by the lead scientist (ALB). Detailed inclusion/exclusion criteria are provided in Table 1.

Table 1
Detailed PECO study eligibility criteria.

Inclusion criteria	Exclusion criteria
Participants/population (human studies or experimental model systems) • Humans • Non-human animals, including laboratory animal studies • In silico studies or in vitro models utilizing organs, tissues, cell lines, or cellular components	• Free living non-human organisms including wildlife, aquatic species, or plants
Exposure • Exposure to MTR mining activities including residential proximity or occupational exposure, environmental measures (e.g., air, water levels) • Exposure to mixtures collected from MTR mining areas in an experimental setting	• Exposure to single chemical components of MTR mining • Studies with unspecified type of mining conducted prior to widespread use of MTR mining or in geographic areas without MTR mining • Exposure to coal samples, dust or leachates in vitro
Comparators • Vehicle-only treatment controls in experimental studies	• Case series of miners, descriptive without comparator
Outcomes • Human health-relevant outcomes, including measures of general well-being	• Environmental impacts
Publications (e.g., language restrictions, use of conference abstracts) • Study must contain original data and must be peer-reviewed • Studies published in a language other than English will be translated for review	• Articles with no original data, e.g., editorials, reviews • Non-peer reviewed articles: Conference presentations or other studies published in abstract form only, grant awards, and theses/dissertations • Retracted articles