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Review Article

Coal operations and cancer in the US: A systematic review

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ABSTRACT

Objectives: Soon after declaring its first national energy emergency in January 2025, the US government committed to increasing coal production and use. Coal operations (e.g., mining, processing, burning, waste management) not only contribute to climate change but also have environmental and public health consequences that may influence cancer risk and outcomes. The aim of this systematic review is to synthesize published evidence on cancer risk and outcomes associated with exposure to coal operations in the US.

Study design: Systematic review.

Methods: We searched PubMed, Embase, Scopus, and CINAHL for quantitative studies published in English between January 1980 and April 2025 evaluating any type of exposure to coal operations and cancer outcomes in the US. Grey literature, non-epidemiological studies, and studies that used cancer cases as controls were excluded. Risk of bias was assessed using ROBINS-E.

Results: The search identified 3065 unique articles, 45 of which were included. All 18 studies that evaluated residential exposures and cancer mortality found statistically significant associations. Similarly, all occupational studies published after 2003 found statistically significant associations with increased cancer mortality. Competing risks, healthy worker bias, and ecological fallacy were the most common limitations of studies included in the review. Findings from 19 studies evaluating either residential or occupational exposure to coal operations and cancer incidence were mixed, and no significant association was found with residential exposure in the single study of cancer-related hospitalizations. Surveillance and research infrastructure supported by the US federal government was used in 82% of studies evaluating the association between coal operations and cancer.

Conclusions: Occupational and residential exposure to coal operations are associated with worse cancer mortality, underscoring the importance of public health surveillance and research efforts to inform local decision-making on initiating and/or expanding coal operations in the US.

1. Introduction

In January 2025, the US declared its first national energy emergency, and soon after announced plans to scale up coal production and usage.[1,2] As one of the world's largest energy consumers, the prospect of increased coal reliance raises concerns about higher greenhouse gas emissions globally,[3] and potential health impacts on local populations working at and/or living near coal mining, processing, burning, and waste management sites. Importantly, the power to expand coal operations in the US rests with the very communities most likely to bear the health consequences of coal expansion because permits for coal operations are granted by US state or county authorities.

Cancer is the second leading cause of death in the US,[4] with disproportionately high incidence and mortality rates in regions poised for expanding coal activities.[5] The simultaneous rollback of environmental protections and incentives for coal expansion risks amplifying exposure to carcinogens and other pollutants in surrounding communities.[6] While the carcinogenicity of single pollutants released by coal operations, including cadmium and chromium released during coal combustion and concentrated in coal waste,[7,8] and some coal-related occupational activities,[9,10] is well-established, people living or working near coal operations are exposed to complex mixtures of pollutants, which may have compounding detrimental health consequences throughout the cancer control continuum. Increased exposure to pollutants can also cause economic burden on communities resulting from premature mortality, increased healthcare costs, and degradation of

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natural resources that support local livelihoods and wellbeing.[11]

Two previous reviews examined research on the association between exposure to coal mining and cancer incidence and mortality. One only examined occupational exposures,[12] and the other, which encompassed both occupational and residential exposures, did not include studies published after 2012.[13] Moreover, neither examined exposures throughout coal's life cycle (e.g., mining, processing, burning, waste management) or outcomes across the cancer control continuum (e.g., prevention, diagnosis, treatment, survivorship, end-of-life care). This systematic review aims to characterize the associations between any type of exposure to any coal operation and any cancer outcome in the US. Such an assessment is urgently needed to inform local decision-making regarding expansion of coal operations.

2. Methods

2.1. Search strategy and selection criteria

In this systematic review, conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Supplemental Table 1), studies were identified using "Cancer" or "Neoplasm" and "Coal" as the search terms in PubMed (full search strategy was ("Neoplasms"[Mesh] OR cancer* OR carcinoma* OR malignan* OR neoplasm*) AND ("Coal"[Mesh] OR "Coal Mining"[Mesh] OR coal OR "coal mining" OR "coal-fired" OR "coal combustion")), Embase, CINAHL, and Scopus electronic databases. Risk of bias was assessed using ROBINS-E.[14] Two investigators (LMN and RS) independently screened articles, extracted data, assessed study quality, then resolved differences and summarized findings. Study authors were contacted for clarification as needed.

Quantitative studies published in English between January 1980 and April 2025 were included. Grey literature, non-epidemiologic studies, studies that did not focus on coal operations and cancer outcomes,[15–18] used individuals diagnosed with cancer as controls,[19,20] or focused on populations outside the US were excluded. Coal operations were defined as mining, processing, burning (i.e., coal-fired power plants), and coal waste management.

2.2. Data analysis

Abstracted study characteristics included study design, funding source, data source, geographic setting, study population characteristics (sample size, age, gender, race/ethnicity), exposure ascertainment method, comparison group, covariates, cancer outcomes, effect measures, and statistical significance ($p < 0.05$).

3. Results

Of the 3065 unique articles identified, 159 were further evaluated following abstract review, 33 of which met the inclusion criteria. Twelve

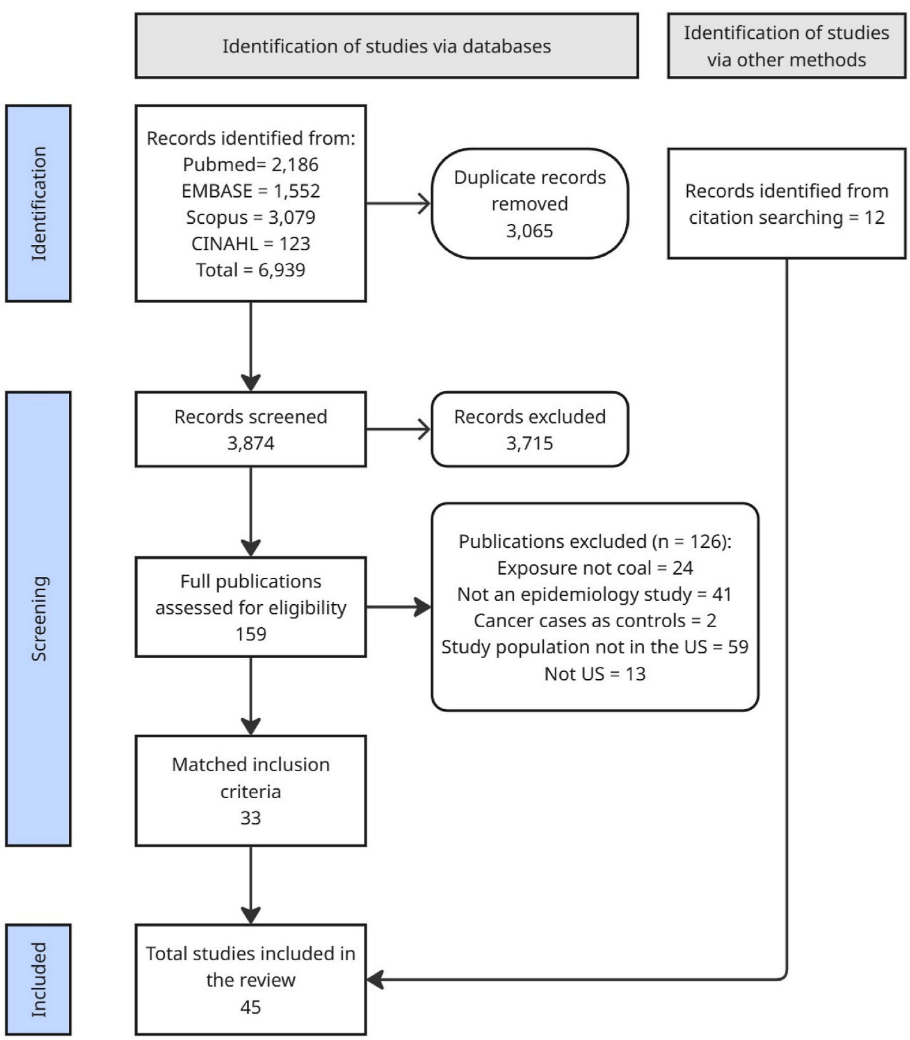

Fig. 1. Study selection.

additional studies were identified from articles' reference lists, with a total of 45 included studies (Fig. 1). Most studies (53•3%) were published after 2012 (Table 1). All studies were observational with cross-sectional (55•6%), case-control (26•7%), or cohort (17•8%) designs. Only two types of exposure to coal operations were evaluated, occupational (31•1%) and residential (68•9%). Outcomes evaluated included cancer incidence (42•2%), cancer-related hospitalizations (2•2%), and cancer mortality (62•2%). The most common cancer types evaluated were cancers of the respiratory tract (55•6%), followed by all cancer sites combined (35•6%).

Most studies (82•2%) relied on research and/or health services infrastructure supported by the US federal government for ascertaining exposure to coal operations, such as county-level coal production data from the Energy Information Administration (EIA) or occupational cohorts established by the National Institute of Occupational Safety and Health (NIOSH), cancer outcomes, such as death records from the Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS), or potential confounders, such as smoking prevalence from the CDC Behavioral Risk Factor Surveillance System (BRFSS). The federal government was also the most mentioned source of funding (40•0%), followed by industry (8•9%).

There was great heterogeneity in exposure metrics, outcome definitions, and effect measures, and all studies were susceptible to some degree of bias, precluding quantitative synthesis of study results. Subgroup and qualitative synthesis were considered but not pursued due to substantial heterogeneity. For example, exposure metrics included county-level coal production, modeled air pollution from coal combustion, and implementation of coal-related regulation. Heterogeneity in effect measures included visual evaluation of confidence intervals, correlation and regression coefficients, standardized incidence or mortality ratios (SIR, SMR), odds ratios (OR), risk ratios (RR), hazard ratios (HR), or prevalence ratios (PR).

Risk of bias across studies is summarized in Supplemental Table 2. Biases would primarily move estimates towards the null. Importantly, none of the studies included in the review applied available methods to account for competing risks, a common issue in evaluating health outcomes such as cancer, which is often asymptomatic and has long latency periods, potentially underestimating reported associations. Studies using vital records and/or administrative data, such as coal mining listed as occupation in death certificates or participation in government-sponsored coal mining and health programs, such as the Coal Workers' Health Surveillance Program (CWHSP) or the Department of Labor (DOL) Federal Black Lung Program (FBLP), were prone to under-ascertainment of exposure, which can underestimate associations. Studies that used area-level (i.e., ecological fallacy) or self-reported (i.e., recall bias, survivor bias) measures of exposure and/or outcome can either over- or under-estimate associations.

To facilitate comparison across studies and interpretation of results, two types of exposure to coal operations– occupational and residential—were used for synthesizing study findings.

3.1. Occupational exposure to coal operations

Of the fourteen studies that examined occupational exposure to coal operations, 13 focused on mining and one focused on coal-fired power plants (Fig. 2). All studies were subject to competing hazards and healthy worker bias, and studies that compared different levels of exposure within the same cohort were also subject to the healthy worker effect (Supplemental Table 2). Most studies (9) were case-control, and eight studies leveraged information collected by NIOSH (Supplemental Table 3).

All four studies that evaluated cancer incidence used a case-control design. Studies that dichotomized self-reported occupational exposure to coal into never/ever found statistically significant associations with higher odds of acute myeloid leukemia,[21] and lung cancer diagnoses.[22] In contrast, studies that evaluated the association between different

Table 1
Studies characteristics.

Studies Characteristics	N (%)
Publication year	
1983 – 1992	5 (11.1%)
1993 – 2002	5 (11.1%)
2003 – 2012	11 (24.4%)
≥2013	24 (53.3%)
Geographical Setting	
Single State	19 (42.2%)
Regional	6 (13.3%)
National	21 (46.7%)
Data Source[a]	
Federal Government	37 (82.2%)
State Government[d]	12 (26.7%)
Other	17 (37.8%)
Funding[a]	
Federal Government	18 (40.0%)
Industry	4 (8.9%)
Other	10 (22.2%)
Study Design	
Cross-sectional	25 (55.6%)
Case-control	12 (26.7%)
Cohort	8 (17.8%)
Quality Rating	
3: Case-control or retrospective cohort studies	20 (44.4%)
4: Cross-sectional study	25 (55.6%)
Exposure Type	
Residential	30 (68.2%)
Occupational	14 (31.8%)
Coal Operations[a]	
Mining	34 (75.6%)
Power Plant	10 (22.2%)
Waste	3 (6.7%)
Components of Cancer Continuum[a]	
Cancer Incidence	19 (42.2%)
Cancer Mortality	28 (62.2%)
Hospitalization	1 (2.2%)
Cancer Site[a]	
All	16 (35.6%)
Respiratory[b]	25 (55.6%)
Gastric	6 (13.3%)
Lymphomas	5 (11.1%)
Leukemia	4 (8.9%)
Cancer Outcome Identification[a]	
CDC[c]	23 (51.1%)
Death Certificate	13 (28.9%)
Cancer Registry	11 (24.4%)
Self-reported	4 (8.9%)
Exposure Identification	
<u>Occupational</u>	
NIOSH[d]	8 (17.8%)
Self-reported	5 (11.1%)
<u>Residential</u>	
Energy Information Administration	10 (22.2%)
Environmental Protection Agency	7 (15.6%)
Satellite Image	3 (6.7%)
Other	7 (15.6%)
Comparison Group	
Lower or no coal residential exposure	20 (44.4%)
Lower or no occupational exposure	10 (22.2%)
US population	7 (15.6%)
Other	8 (17.8%)
Age[a]	
0-16	1 (2.2%)
17-30	22 (48.9%)
30-64	25 (55.6%)
≥65	25 (55.6%)
Not specified	20 (44.4%)
Gender	
Men only	9 (20.0%)
Women only	1 (2.2%)
Men and Women	30 (66.7%)
Not specified	5 (11.1%)
Race and Ethnicity	
Black only	1 (2.2%)
White only	9 (20.0%)

(*continued on next page*)

Table 1 (*continued*)

Studies Characteristics	N (%)
≥90% White	14 (31.1%)
Other combination of races & ethnicities	5 (11.1%)
Not specified	16 (35.6%)
Sample Size	
Individuals	
<500	7 (15.6%)
500-999	5 (11.1%)
1000–9999	9 (20.0%)
10,000–99,999	6 (13.3%)
≥100,000	5 (11.1%)
Counties	
<100	6 (13.3%)
100-499	4 (8.9%)
≥500	3 (6.7%)

Notes.
[a] Categories are not mutually exclusive, and studies were included in multiple categories.
[b] Includes lung and bronchus.
[c] Includes data sources derived from the National Center for Health Statistics (e.g., CDC WONDER, SEER mortality file, the Mortality and Population Data System).
[d] Includes occupational exposure data from the National Coal Workers' Autopsy, the National Coal Study, and the National Coal Workers Health Surveillance Program.

levels of occupational exposure, such as number of years of employment, found no association with multiple myeloma diagnosis,[23] or malignant lung biopsy.[24]

Among the ten studies that evaluated cancer mortality, five applied a case-control design. Two studies used death certificates to identify cases and derived exposure information posthumously using either next-of-kin interviews,[25] or coal mining listed as usual occupation in death certificates,[26] and reported no association. The other three studies applied a nested case-control design within the same four NIOSH occupational cohort populations,[27–29] and found longer occupational exposure to underground coal mining (self-reported at baseline) was associated with increased mortality from leukemia,[29] but not lung or gastric cancers.[27,28]

Among the four cohort studies that evaluated the association between occupational exposure to coal mining and cancer mortality, three used the NIOSH National Coal Study cohort.[30–32] The first study had 10 years of follow-up, excluded participants aged ≥65 years, compared different levels of cumulative exposure to coal mining (self-reported at baseline) within the cohort and found no association between higher levels of exposure and lung cancer mortality.[32] The two subsequent studies had longer follow-up times (24 and 37 years, respectively), and found lung cancer mortality was significantly higher among the cohort population compared to the general population in the US (Fig. 3).[30,31] Consistent with these findings, the last cohort study found occupational exposure to coal mining, ascertained through participation in either the NIOSH CWHSP or the FBLP, was significantly associated with higher lung cancer mortality compared to the general population.[33] The only cross-sectional study found occupational exposure to coal mining (ascertained through FBPL listed as the primary payer in Medicare claims) was associated with significantly higher lung and prostate cancer deaths, compared to Medicare enrollees without FBPL listed.[34]

Fig. 2. Summary of studies included in the review, by type of exposure and outcome evaluated and reported association.
Notes: All studies reporting statistically significant direct associations (defined as $p < 0.05$), with higher levels of coal exposure statistically significantly associated with higher cancer incidence or mortality.

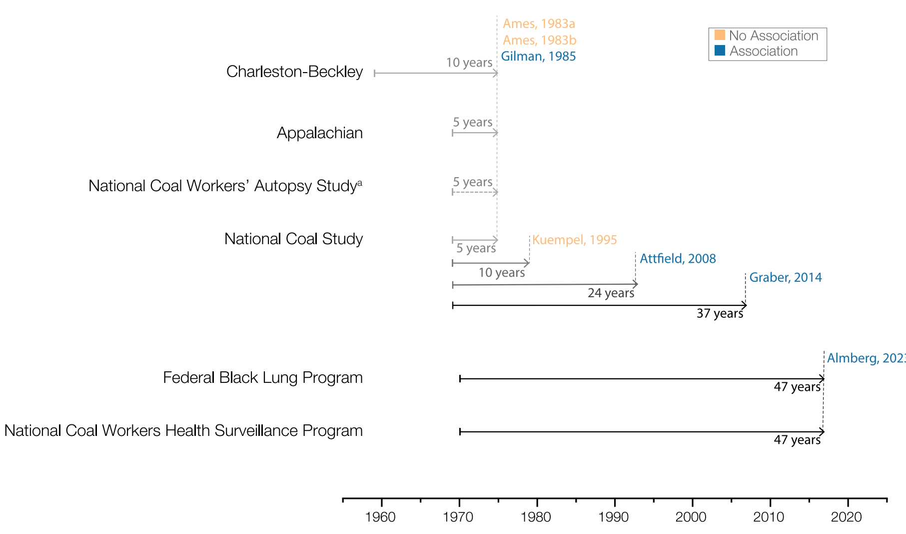

Fig. 3. Occupational cohort used in studies included in the review by number of years of follow-up and reported association.
Notes: Studies published more recently benefited from longer follow-up periods in occupational cohorts.[a] No follow up period for the National Coal Workers' Autopsy Study, line indicates when study was established (1969). All studies reporting statistically significant associations (defined as $p < 0.05$) found a positive direction of effect, with higher levels of coal exposure associated with higher cancer incidence or mortality.

3.2. Residential exposure to coal operations

Of the 31 studies that evaluated the association between residential exposures to coal operations and cancer outcomes, 21 focused on mining, 9 focused on coal-fired power plants, and one focused on coal waste (Fig. 2). Notably, comparison groups often also resided near coal operations (Fig. 4), likely resulting in exposure misclassification and underestimation of the associations (Supplemental Table 2). Most studies (28) used area-level measures of exposure, ten of which used EIA data (Supplemental Table 4).

Of the 19 studies that evaluated residential exposure to coal mining, only one examined healthcare use and reported no association between county-level coal production and odds of lung cancer listed as the primary diagnosis in short-term hospitalizations.[35]

Nine studies evaluated the association between residential exposure to coal mining and cancer incidence, with mixed results. Three studies relied on self-reported cancer diagnosis, which is subject to survivor bias. One study identified a statistically significant association with individual diagnosis of any cancer,[36] another didn't,[37] and the most recent study found an association with cancer death in the household within 5 years, but not with individual self-reported cancer diagnosis.[38]

All other six studies used state cancer registry data, three of which were conducted in Kentucky. Studies found coal production coincided with clusters of high lung cancer incidence,[39] and somewhat with clusters of rare pediatric brain cancers,[40] but not with higher odds of lung cancer diagnosis across the state.[41] Similarly, a cluster of small intestinal neuroendocrine tumors coincided with historical coal mining in Utah,[42] and residing in a county with coal mining and burning operations was significantly associated with higher incidence of multiple myeloma and leukemia in Texas.[43] The last study evaluated both incidence and mortality, and found populations residing in counties with recent coal mining had significantly higher overall, lung, and colorectal cancer incidence rates, as well as significantly higher colorectal, but lower prostate cancer mortality rates, compared to populations residing in never-mined counties in Illinois.[44]

Consistent with these findings, all other studies evaluating residential exposure to coal operations and cancer mortality found statistically significant associations. Most studies (11) focused on coal mining and found county-level coal production was associated with higher overall cancer mortality throughout the US,[45,46] as well as regionally, where exposure to mountain-top coal mining in Appalachia was significantly associated with higher overall,[47–51] lung,[47–49,52–54] breast,[54] as well as leukemia, colorectal, anus, and liver cancer mortality.[48] Finally, Hendryx et al. found higher respiratory cancer mortality after mountaintop coal mining was introduced in Appalachia in response to implementation of the Clean Air Act, which incentivized a shift towards mining low-sulfur coal reserves in the region.[55]

Ten studies evaluated the association between exposure to pollutants from coal-fired power plants and cancer outcomes. While findings on cancer incidence were mixed, findings from studies that focused on cancer mortality were consistent. For example, among the four studies that leveraged cancer registry data to evaluate cancer incidence, two studies found higher annual dioxin emissions were statistically significant associated with non-Hodgkin lymphoma (NHL) and hepatocellular carcinoma diagnoses,[56,57] whereas smaller studies found no association between residential proximity to coal-fired power plants and NHL,[58]

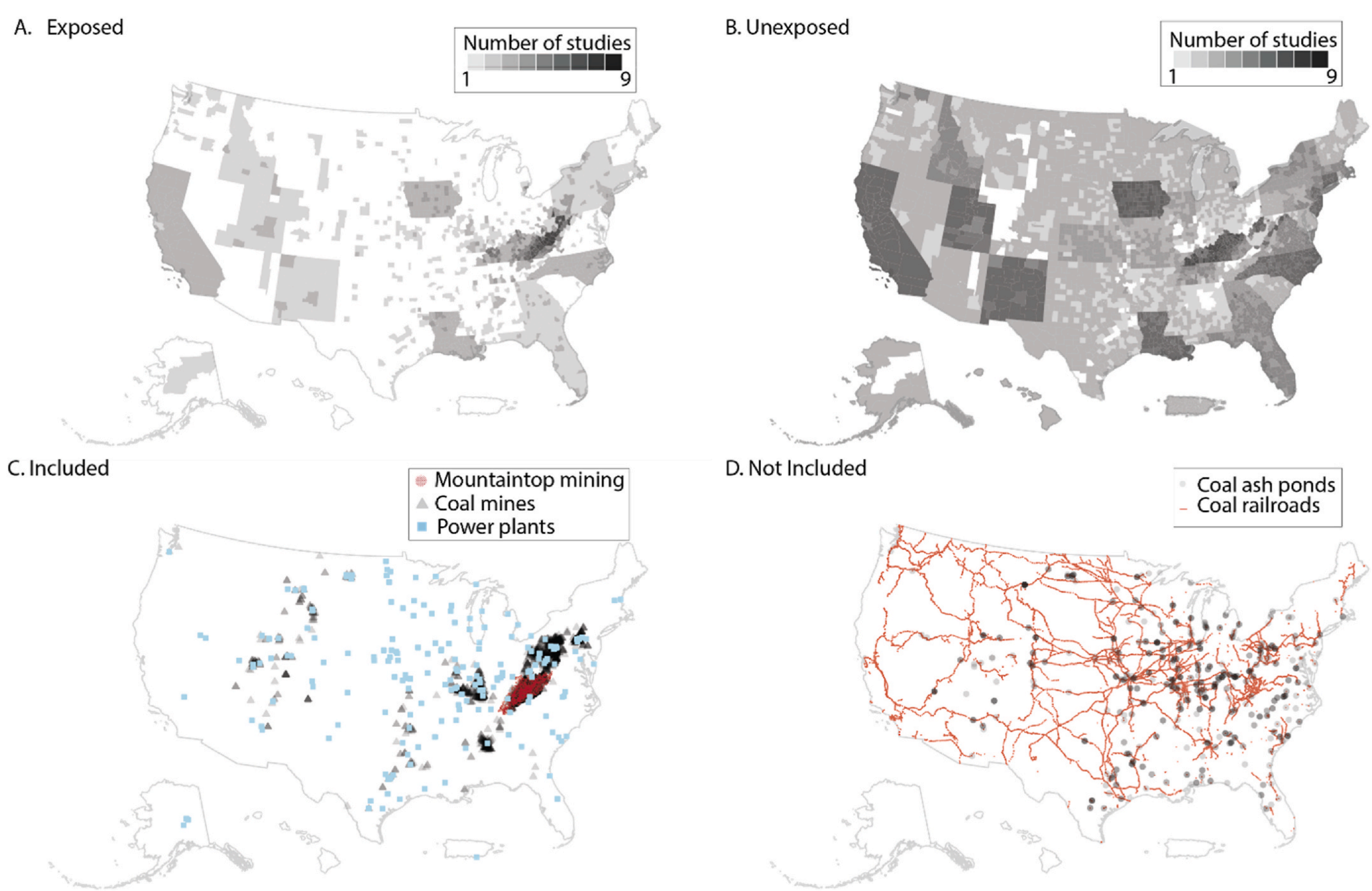

Fig. 4. Geographic distribution of exposed and unexposed populations and types of coal operations in studies included in this review
Notes: **A.** Geographic distribution of locations used to define "exposed" populations using study-specific criteria. **B.** Geographic distribution of locations used to define the comparison groups (i.e., unexposed), defined as individuals outside the study-specific exposure thresholds. **C.** Types of coal operations evaluated across studies included in the review. **D.** Types of coal operations not assessed by studies included in this review.

lung,[59] or self-reported breast cancer diagnosis.[60]

In agreement with evidence from studies evaluating residential exposure to coal mining, higher exposure to air pollution from burning coal was also significantly associated with higher state-level respiratory, esophageal, colorectal, bladder, Hodgkin's lymphoma, cervical, endometrial, and breast cancer mortality,[61] and with individual-level overall and lung cancer mortality in two national cohort studies.[62,63] Finally, Li et al. reported a 60% reduction in lung cancer attributable fraction associated with reductions in pollution resulting from the North Carolina Clean Smokestack Act.[64]

Exposure to coal waste management sites was also consistently associated with cancer mortality. Consuming fish caught in a coal strip pond was the most common exposure in a brain cancer incidence and mortality cluster in Missouri,[65] and in West Virginia, population-weighted proximity to coal impoundment dams was significantly associated with higher overall, respiratory, and breast cancer mortality,[51] and proximity to injection sites was significantly associated with mortality from other cancers.[54]

4. Discussion

This systematic review of 45 studies provided insights into the associations between exposure to coal operations and cancer outcomes in communities likely to be impacted by federal government directives to expand coal activities in the US in 2025. Despite great heterogeneity in methodological approaches, which precluded quantitative synthesis of study results, most studies found statistically significant associations between residential and occupational exposure to coal operations and cancer outcomes, especially cancer mortality. The consistency of these findings highlights the importance of understanding the detrimental health consequences of coal activities to inform local permitting decision-making in these communities.

All studies evaluating residential exposure to coal operations found a statistically significant association with higher cancer mortality,[38,44–55,62–64] while studies evaluating an association with cancer incidence reported mixed results.[22,24,36–42,44,59] Ecological fallacy was a concern among all studies using area-level measures of exposure and/or outcome. Nonetheless, area-level measures of exposure to geographically defined environmental factors (e.g., proximity to coal operations) are a reasonable proxy for individual exposure gradients. In contrast, area-level measures of individual behavior (e.g., prevalence of smoking) cannot reliably approximate individual-level factors. Therefore, residual confounding by smoking remains a concern where area-level measures were used. Finally, most studies evaluating cancer mortality shared data sources (i.e., surveillance systems supported by the federal government) that were unlikely to introduce bias given consistent population-based data collection over time. Sustained federal investment in research infrastructure and surveillance systems will remain critical for monitoring and mitigating the health effects of coal operations on local communities.

Similarly, all recent studies that evaluated occupational exposure to coal mining found a statistically significant association with higher cancer mortality compared to the general population.[30,31,33,34] In contrast, earlier studies compared different levels of exposure within the same cohort.[27–29,32] However, this strategy is susceptible to healthy worker survivor effect, a type of bias known to mask dose-response relationships.[66] Therefore, the results of more recent studies, which benefitted from longer follow-up periods, are not only more consistent, but also more reliable. These consistent findings of associations between occupational exposure to coal operations and worse cancer mortality underscore the importance of weighing the potential economic benefits of job creation from coal expansion against the health costs to local communities.

Randomizing individuals to coal exposure is both infeasible and unethical. Consequently, all studies were observational and implemented different strategies to address the inherent difficulties and sources of bias. The consistency across studies' findings despite these methodological limitations suggests the association between occupational and residential exposure to coal operations and cancer mortality is robust.

Key knowledge gaps remain. For example, only one study evaluated cancer outcomes in children,[40] who may be especially vulnerable to pollutants released by coal operations due to physiologic, metabolic, and behavioral factors.[67] Additionally, only two studies evaluated changes in cancer outcomes following policy changes.[55,64] Finally, most studies focused on residential or occupational exposure to coal mining. However, each stage of coal's life cycle can adversely affect the economic and health well-being of local communities.[68]

Burning coal not only releases pollutants into the surrounding air,[69] but also concentrates metals (e.g., arsenic, cadmium, and chromium) in the ash.[70] In the US, coal waste is stored in coal ash ponds, which are prone to leakage and can contaminate water sources.[71–73] Additionally, coal ash pond spills can have catastrophic consequences for local communities.[74] Coal also has the highest greenhouse emission intensity of all energy sources.[75] Given coal's contribution to both climate change and air pollution, expansion of US coal operations has global implications. Climate change already affects populations worldwide,[76] including in the US,[77] where impacts of climate-driven disasters on cancer care and outcomes are already measurable.[78,79] Climate-driven extreme weather events can also increase exposure to carcinogens in local communities.[80] For example, with increasing rainfall intensity and exacerbation of extreme weather events,[81] the frequency of coal ash ponds spills could increase – underscoring the critical need for evidence-based protective policies and practices.

No studies evaluated cancer outcomes associated with coal transportation,[82] coal ash used as structural fill,[70] or occupational exposures during coal ash cleanup efforts.[83] Finally, no study evaluated the association between exposure to coal and efficacy or cost of cancer treatment and/or survivorship care. These are important topics for future research.

Historically, federal government-supported research – both intramural and extramural - provided the scientific evidence for policies and regulations that improved occupational health and safety in coal mines,[84–86] and protected the US population from industry pollution (e.g., the Clean Air Act).[87,88] However, recent policy shifts, such as declaration of the energy emergency,[2] regulatory rollbacks,[6,89] cuts to federally funded research,[90] and dismantling of occupational health programs,[91] are likely to simultaneously incentivize an increase in coal activities and limit the ability of public health professionals, policymakers, and local decision-makers to monitor, understand, and act on coal-related occupational and residential hazards.

This systematic review drew from peer-reviewed publications across multiple databases and included studies with a wide range of exposures and outcomes. Additionally, we searched reference lists of included articles to identify additional published studies that may have been missed in electronic searches. Despite these efforts, we may have missed some relevant studies. Finally, it was not possible to quantitatively synthesize the studies due to heterogeneity in study measures.

Exposure to coal operations is consistently associated with worse cancer mortality, underscoring the need for continued support for surveillance, research, regulatory action, and occupational health programs to mitigate detrimental health consequences of potentially increasing coal activities in the US.

Ethical statement

Ethical approval was not required for this systematic review of published literature.

Registration of protocol

This review was not registered.

Author contributions

LMN, RS: data curation.

LMN, RS: conceptualization, investigation, writing-original draft, writing-review and editing.

LMN, KRY, GM: conceptualization, writing-review and editing.

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Declaration of competing interest

KRY has received royalties from coal activities conducted on inherited and multi-heir owned properties in eastern Kentucky.

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N/A.

Appendix A. Supplementary data

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References

1. The White House. Reinvigorating America's beautiful clean coal industry and amending executive order 14241. https://www.whitehouse.gov/presidential-actions/2025/04/reinvigorating-americas-beautiful-clean-coal-industry-and-amending-executive-order-14241/; 2025. Accessed May 10, 2025.
2. The White House. Declaring a national energy emergency. https://www.whitehouse.gov/presidential-actions/2025/01/declaring-a-national-energy-emergency/; 2025. Accessed May 10, 2025.
3. International Energy Agency. *Phasing out Unabated Coal*; 2021. https://www.iea.org/reports/world-energy-outlook-2021.
4. Siegel RL, Kratzer TB, Giaquinto AN, Sung H, Jemal A. Cancer statistics. *CA Cancer J Clin*. 2025;75(1):10–45, 2025.
5. Siegel RL, Sahar L, Robbins A, Jemal A. Where can colorectal cancer screening interventions have the most impact? *Cancer Epidemiol Biomarkers Prev*. 2015;24(8):1151–1156.
6. Environmental Protection Agency. EPA launches biggest deregulatory action in U.S. history. https://www.epa.gov/newsreleases/epa-launches-biggest-deregulatory-action-us-history; 2025. Accessed May 10, 2025.
7. International Agency for Research on Cancer. *Beryllium, Cadmium, Mercury, and Exposures in the Glass Manufacturing Industry*. World Health Organization; 1997.
8. International Agency for Research on Cancer. *Arsenic, Metals, Fibres, and Dusts*. 2012.
9. International Agency for Research on Cancer. *Some Non-heterocyclic Polycyclic Aromatic Hydrocarbons and Some Related Exposures*. 2010.
10. International Agency for Research on Cancer. *Chemical Agents and Related Occupations*. 2012.
11. The Organization for Economic Co-operation and Development. The economic consequences of outdoor air pollution. https://www.oecd.org/en/publications/2016/06/the-economic-consequences-of-outdoor-air-pollution_g1g68583.html; 2016.
12. Alif SM, Sim MR, Ho C, Glass DC. Cancer and mortality in coal mine workers: a systematic review and meta-analysis. *Occup Environ Med*. 2022;79(5):347–357.
13. Jenkins WD, Christian WJ, Mueller G, Robbins KT. Population cancer risks associated with coal mining: a systematic review. *PLoS One*. 2013;8(8), e71312.
14. Higgins JPT, Morgan RL, Rooney AA, et al. A tool to assess risk of bias in non-randomized follow-up studies of exposure effects (ROBINS-E). *Environ Int*. 2024;186, 108602.
15. Annie FH, Crews C, Drabish K, Mandapaka S. Effect of coal mining on health outcomes between Male and female miners in Southern West Virginia: a brief report. *Cureus*. 2023;15(11), e49009.
16. Cocco P, Ward MH, Dosemeci M. Risk of stomach cancer associated with 12 workplace hazards: analysis of death certificates from 24 states of the United States with the aid of job exposure matrices. *Occup Environ Med*. 1999;56(11):781–787.
17. Unrine JM, Slone SA, Sanderson W, et al. A case-control study of trace-element status and lung cancer in Appalachian Kentucky. *PLoS One*. 2019;14(2), e0212340.
18. Wingo PA, Tucker TC, Jamison PM, et al. Cancer in Appalachia, 2001-2003. *Cancer*. 2008;112(1):181–192.
19. Ames RG, Gamble JF. Lung cancer, stomach cancer, and smoking status among coal miners. A preliminary test of a hypothesis. *Scand J Work Environ Health*. 1983;9(5):443–448.
20. Morabia A, Markowitz S, Garibaldi K, Wynder EL. Lung cancer and occupation: results of a multicentre case-control study. *Br J Ind Med*. 1992;49(10):721–727.
21. Poynter JN, Richardson M, Roesler M, et al. Chemical exposures and risk of acute myeloid leukemia and myelodysplastic syndromes in a population-based study. *Int J Cancer*. 2017;140(1):23–33.
22. Muscat JE, Stellman SD, Richie Jr JP, Wynder EL. Lung cancer risk and workplace exposures in black men and women. *Environ Res*. 1998;76(2):78–84.
23. Demers PA, Vaughan TL, Koepsell TD, et al. A case-control study of multiple myeloma and occupation. *Am J Ind Med*. 1993;23(4):629–639.
24. Balakrishnan B, Sarkar S, Choi J, Patel R, Adkins T, Fang W. Risk factors associated with malignant lung nodules in smokers with coal worker's pneumoconiosis: an exploratory case-control study. *Open Publ Health J*. 2024;17(1).
25. Weinberg GB, Kuller LH, Stehr PA. A case-control study of stomach cancer in a coal mining region of Pennsylvania. *Cancer*. 1985;56(3):703–713.
26. Cocco P, Ward MH, Dosemeci M. Occupational risk factors for cancer of the gastric cardia. Analysis of death certificates from 24 US states. *J Occup Environ Med*. 1998;40(10):855–861.
27. Ames RG. Gastric cancer and coal mine dust exposure. A case-control study. *Cancer*. 1983;52(7):1346–1350.
28. Ames RG, Amandus H, Attfield M, Green FY, Vallyathan V. Does coal mine dust present a risk for lung cancer? A case-control study of U.S. coal miners. *Arch Environ Health*. 1983;38(6):331–333.
29. Gilman PA, Ames RG, McCawley MA. Leukemia risk among U.S. white male coal miners. A case-control study. *J Occup Med*. 1985;27(9):669–671.
30. Attfield MD, Kuempel ED. Mortality among U.S. underground coal miners: a 23-year follow-up. *Am J Ind Med*. 2008;51(4):231–245.
31. Graber JM, Stayner LT, Cohen RA, Conroy LM, Attfield MD. Respiratory disease mortality among US coal miners; results after 37 years of follow-up. *Occup Environ Med*. 2014;71(1):30–39.
32. Kuempel ED, Stayner LT, Attfield MD, Buncher CR. Exposure-response analysis of mortality among coal miners in the United States. *Am J Ind Med*. 1995;28(2):167–184.
33. Almberg KS, Halldin CN, Friedman LS, et al. Increased odds of mortality from non-malignant respiratory disease and lung cancer are highest among US coal miners born after 1939. *Occup Environ Med*. 2023;80(3):121–128.
34. Kurth L, Halldin C, Laney AS, Blackley DJ. Causes of death among federal black lung benefits program beneficiaries enrolled in medicare, 1999-2016. *Am J Ind Med*. 2020;63(11):973–979.
35. Hendryx M, Ahern MM, Nurkiewicz TR. Hospitalization patterns associated with Appalachian coal mining. *J Toxicol Environ Health A*. 2007;70(24):2064–2070.
36. Hendryx M, Wolfe L, Luo J, Webb B. Self-reported cancer rates in two rural areas of West Virginia with and without mountaintop coal mining. *J Community Health*. 2012;37(2):320–327.
37. Hendryx M, Ahern MM. Relations between health indicators and residential proximity to coal mining in West Virginia. *Am J Publ Health*. 2008;98(4):669–671.
38. Hendryx M. Personal and family health in rural areas of Kentucky with and without mountaintop coal mining. *J Rural Health*. 2013;29(Suppl 1):s79–s88.
39. Christian WJ, Huang B, Rinehart J, Hopenhayn C. Exploring geographic variation in lung cancer incidence in Kentucky using a spatial scan statistic: elevated risk in the Appalachian coal-mining region. *Publ Health Rep*. 2011;126(6):789–796.
40. Christian WJ, Walker CJ, McDowell J, et al. Geographic and temporal trends in pediatric and young adult brain tumors in Kentucky, 1995-2019. *Cancer Epidemiol*. 2024;88, 102499.
41. Christian WJ, Walker CJ, Huang B, Levy JE, Durbin E, Arnold S. Using residential histories in case-control analysis of lung cancer and mountaintop removal coal mining in Central Appalachia. *Spat Spatiotemporal Epidemiol*. 2020;35, 100364.
42. VanDerslice J, Taddie MC, Curtin K, et al. Early life exposures associated with risk of small intestinal neuroendocrine tumors. *PLoS One*. 2020;15(4), e0231991.
43. Strom SS, Spitz MR, Cech IM, Annegers JF, Downs TD. Excess leukemia and multiple myeloma in a mining county in northeast Texas. *Tex Med*. 1994;90(2):55–59.
44. Mueller GS, Clayton AL, Zahnd WE, et al. Manuscript title: geospatial analysis of cancer risk and residential proximity to coal mines in Illinois. *Ecotoxicol Environ Saf*. 2015;120:155–162.
45. Hendryx M, Fedorko E, Halverson J. Pollution sources and mortality rates across rural-urban areas in the United States. *J Rural Health*. 2010;26(4):383–391.
46. Matheis M. Natural resource extraction and mortality in the United States. *J Environ Manag*. 2019;235:112–123.
47. Crosby L, Tatu C, Charles K. Lung and bronchus cancer deaths in Boone County, Wv before and after mountaintop removal mining. *Journal of Rare Disorders: Diagnosis and Therapy*. 2016;2(1):1–8.
48. Ahern M, Hendryx M. Cancer mortality rates in Appalachian mountaintop coal mining areas. *J Environ Occup Sci*. 2012;1(2):63–70.
49. Buchanich J, Talbott E, Youk A, Potter A, Marshall L. Comparison of mortality rates between Appalachian coal mining counties with non-coal mining. *SME Transactions*. 2013.
50. Buchanich JM, Balmert LC, Youk AO, Woolley SM, Talbott EO. General mortality patterns in appalachian coal-mining and non-coal-mining counties. *J Occup Environ Med*. 2014;56(11):1169–1178.
51. Hendryx M, Fedorko E, Anesetti-Rothermel A. A geographical information system-based analysis of cancer mortality and population exposure to coal mining activities in West Virginia, United States of America. *Geospat Health*. 2010;4(2):243–256.
52. Hendryx M, O'Donnell K, Horn K. Lung cancer mortality is elevated in coal-mining areas of Appalachia. *Lung Cancer*. 2008;62(1):1–7.
53. Woolley SM, Meacham SL, Balmert LC, Talbott EO, Buchanich JM. Comparison of mortality disparities in central appalachian Coal- and non-coal-mining counties. *J Occup Environ Med*. 2015;57(6):687–694.
54. Hitt NP, Hendryx M. Ecological integrity of streams related to human cancer mortality rates. *EcoHealth*. 2010;7(1):91–104.

55. Hendryx M, Holland B. Unintended consequences of the clean air act: mortality rates in Appalachian coal mining communities. *Environ Sci Pol*. 2016;63:1–6.
56. Fisher JA, Medgyesi DN, Deziel NC, Nuckols JR, Ward MH, Jones RR. Residential proximity to dioxin-emitting facilities and risk of Non-Hodgkin lymphoma in the NIH-AARP diet and health study. *Environ Int*. 2024;188, 108767.
57. VoPham T, Bertrand KA, Fisher JA, Ward MH, Laden F, Jones RR. Emissions of dioxins and dioxin-like compounds and incidence of hepatocellular carcinoma in the United States. *Environ Res*. 2022;204(Pt D), 112386.
58. Pronk A, Nuckols JR, De Roos AJ, et al. Residential proximity to industrial combustion facilities and risk of Non-Hodgkin lymphoma: a case-control study. *Environ Health*. 2013;12:20.
59. Ige O, Ratnayake I, Martinez J, et al. A regional study to evaluate the impact of coal-fired power plants on lung cancer incident rates. *Prev Oncol Epidemiol*. 2024;2(1).
60. Rhee J, Medgyesi DN, Fisher JA, et al. Residential proximity to dioxin emissions and risk of breast cancer in the sister study cohort. *Environ Res*. 2023;222, 115297.
61. Grant WB. Air pollution in relation to U.S. cancer mortality rates: an ecological study; likely role of carbonaceous aerosols and polycyclic aromatic hydrocarbons. *Anticancer Res*. 2009;29(9):3537–3545.
62. Kazemiparkouhi F, Honda T, Eum KD, Wang B, Manjourides J, Suh HH. The impact of long-term PM(2.5) constituents and their sources on specific causes of death in a US medicare cohort. *Environ Int*. 2022;159, 106988.
63. Thurston G, Ito K, Lall R, et al. NPACT study 4. Mortality and long-term exposure to PM2.5 and its components in the American cancer society's cancer prevention study II cohort. *Res Rep Health Eff Inst*. 2013.
64. Li YR, Gibson JM. Health and air quality benefits of policies to reduce coal-fired power plant emissions: a case study in North Carolina. *Environ Sci Technol*. 2014;48 (17):10019–10027.
65. Morantz RA, Neuberger JS, Baker LH, Beringer GB, Kaufman AB, Chin TD. Epidemiological findings in a brain-tumor cluster in Western Missouri. *J Neurosurg*. 1985;62(6):856–860.
66. Robins J. A new approach to causal inference in mortality studies with a sustained exposure period - application to control of the healthy worker survivor effect. *Math Model*. 1986;7(9–12):1393–1512.
67. Cohen Hubal EA, Sheldon LS, Burke JM, et al. Children's exposure assessment: a review of factors influencing children's exposure, and the data available to characterize and assess that exposure. *Environ Health Perspect*. 2000;108(6): 475–486.
68. Global Reporting Initiative. Gri 12: coal sector 2022. https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/; 2022.
69. Amster E. Public health impact of coal-fired power plants: a critical systematic review of the epidemiological literature. *Int J Environ Health Res*. 2021;31(5): 558–580.
70. Environmental Protection Agency. Draft risk assessment of coal combustion residuals legacy impoundments and CCR management units. 2023. Prepared by: united States environmental protection agency office of land and emergency management office of resource conservation and recovery. https://www.regulations.gov/document/EPA-HQ-OLEM-2020-0107-0887; 2023.
71. Vengosh A, Cowan EA, Coyte RM, et al. Evidence for unmonitored coal ash spills in Sutton Lake, North Carolina: implications for contamination of lake ecosystems. *Sci Total Environ*. 2019;686:1090–1103.
72. Harkness JS, Sulkin B, Vengosh A. Evidence for coal ash ponds leaking in the Southeastern United States. *Environ Sci Technol*. 2016;50(12):6583–6592.
73. Eaves LA, Keil AP, Rager JE, George A, Fry RC. Analysis of the novel NCWELL database highlights two decades of co-occurrence of toxic metals in North Carolina private well water: public health and environmental justice implications. *Sci Total Environ*. 2022;812, 151479.
74. Environmental Protection Agency. EPA response to Kingston TVA coal ash spill. https://www.epa.gov/tn/epa-response-kingston-tva-coal-ash-spill; 2025. Accessed May 10, 2025.
75. US Energy Information Administration. *How much carbon dioxide is produced per kilowatthour of US electricity generation?*; 2024. https://www.eia.gov/tools/faqs/faq.php?id=74&t=11#:~:text=In%202020%2C%20total%20U.S.%20electricity,CO2%20emissions%20per%20kWh.
76. Intergovernmental Panel on Climate Change. The intergovernmental panel on climate change (IPCC) is the united nations body for assessing the science related to climate change. https://www.ipcc.ch/; 2024.
77. Nogueira LM, Salas RN. No climate havens: the expanding threat of climate change to cancer care. *Nat Rev Cancer*. 2025.
78. Nogueira LM, Crane TE, Ortiz AP, D'Angelo H, Neta G. Climate change and cancer. *Cancer Epidemiol Biomarkers Prev*. 2023;32(7):869–875.
79. Nogueira LM, Sahar L, Efstathiou JA, Jemal A, Yabroff KR. Association between declared hurricane disasters and survival of patients with lung cancer undergoing radiation treatment. *JAMA*. 2019;322(3):269–271.
80. Nogueira LM, Yabroff KR. Climate change and cancer: the environmental justice perspective. *J Natl Cancer Inst*. 2024;116(1):15–25.
81. Marvel K, Su W, Delgado R, et al. *Climate trends*. In: *Fifth National Climate Assessment*. vol. 10. 2023.
82. Aneja VP, Pillai PR, Isherwood A, Morgan P, Aneja SP. Particulate matter pollution in the coal-producing regions of the Appalachian Mountains: integrated ground-based measurements and satellite analysis. *J Air Waste Manag Assoc*. 2017;67(4): 421–430.
83. Gaffney A. Hundreds of workers who cleaned up the country's worst coal ash spill are now sick and dying. https://www.nrdc.org/stories/hundreds-workers-who-cleaned-countrys-worst-coal-ash-spill-are-now-sick-and-dying; 2018.
84. Epstein PR, Buonocore JJ, Eckerle K, et al. Full cost accounting for the life cycle of coal. *Ann N Y Acad Sci*. 2011;1219:73–98.
85. Blackley DJ, Halldin CN, Laney AS. Continued increase in prevalence of coal workers' pneumoconiosis in the United States, 1970-2017. *Am J Publ Health*. 2018; 108(9):1220–1222.
86. Liu T, Liu S. The impacts of coal dust on miners' health: a review. *Environ Res*. 2020; 190, 109849.
87. Environmental Protection Agency. Progress cleaning the air and improving people's health. https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health; 2025. Accessed May 10, 2025.
88. LaCount MD, Haeuber RA, Macy TR, Murray BA. Reducing power sector emissions under the 1990 clean air act amendments: a retrospective on 30 years of program development and implementation. *Atmos Environ*. 2021;245:1–10, 1994.
89. The White House. Fact sheet: president Donald J. Trump lifts burdensome EPA restrictions on coal plants. https://www.whitehouse.gov/fact-sheets/2025/04/fact-sheet-president-donald-j-trump-lifts-burdensome-epa-restrictions-on-coal-plants/; 2025. Accessed May 10, 2025.
90. The White House. *The President's FY 2026 Discretionary Budget Request*; 2025. https://www.whitehouse.gov/omb/information-resources/budget/the-presidents-fy-2026-discretionary-budget-request/. Accessed May 10, 2025.
91. Department of Health and Human Services. HHS announces transformation to make America healthy again. https://www.hhs.gov/press-room/hhs-restructuring-doge.html; 2025. Accessed May 10, 2025.