Examining the Environmental Impacts of Coal Mining in China

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Abstract. Coal remains the primary energy source in China despite its declining role in global energy consumption. While coal mining ensures energy security and economic growth, it has substantial environmental consequences. This study synthesizes secondary data and peer-reviewed literature to examine three major impacts of coal mining: geological disruption, water resource depletion and pollution, and atmospheric contamination. Results show that underground mining causes land subsidence and topographical deformation, while groundwater pumping accelerates aquifer depletion and acid mine drainage formation. Additionally, spontaneous combustion of coal gangue and emissions of SO_2, NO_x, CO, and CH_4 contribute to severe air pollution and climate change. The analysis highlights the urgent need for improved mine water management, land reclamation, and methane mitigation strategies. Future research should integrate field-based monitoring with multi-dimensional ecological assessments to provide a scientific basis for sustainable mining practices and low-carbon transitions.

Keywords: Coal mining, Environmental impacts, Groundwater depletion, Acid mine drainage, Methane emissions, Land subsidence.

1. Introduction

Coal has experienced a steady decline in its share of energy consumption in developed countries since 2021. Nevertheless, it remains the largest source of electricity generation worldwide. In 2024, coal-fired power generation increased by nearly 1%, reaching a record high of 10,700 TWh, with demand in the power sector accounting for almost two-thirds of total coal consumption. Despite global efforts to promote renewable energy, coal continues to be indispensable because of its abundant reserves, relatively low cost, and stable supply, particularly for large-scale industry and power generation.

Data from the International Energy Agency (IEA) further illustrates this trend (Figure 1). As shown, global coal production from 2000 to 2025 has remained at historically high levels, with output in 2023 concentrated in a small number of producing countries. China alone accounted for approximately 4,430 million metric tons (Mt) of coal, representing the largest share of global output. This concentration highlights both China's dominant role in the global coal market and the structural

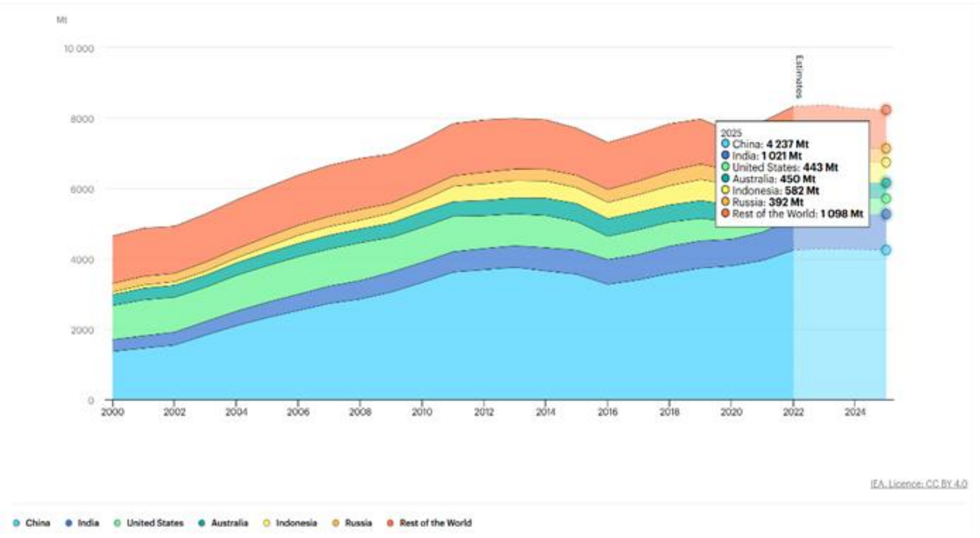

Fig. 1 Global coal production, 2000-20251

However, the expansion of coal mining has also generated profound environmental consequences. The destructive effects of large-scale mining are primarily reflected in three domains: geological changes such as land subsidence and soil instability, water resource depletion and contamination, and atmospheric pollution from greenhouse gas and dust emissions. These challenges have become increasingly pressing as production continues to rise. Accordingly, the aim of this paper is to systematically review the major environmental impacts of coal mining in China, combining secondary data and literature to provide insights for sustainable management and ecological restoration strategies.

2. Methodology

2.1. Total Production and Provincial Distribution in China

According to the CEIC database, China's total coal production in 2023 reached a new record high of approximately 4,710 Mt, reaffirming the country's position as the world's largest coal producer. This increase reflects both strong domestic demand and the continued reliance of China's power sector on coal, despite global calls for decarbonization.

The spatial distribution of production capacity is illustrated in Figure 2, which shows coal production capacity by province. Eight major coal-producing provinces—including Shanxi, Inner Mongolia, Shaanxi, Xinjiang, Guizhou, Shandong, Henan, and Anhui—each exceed 100 million tons annually. These provinces represent the "front line" of national coal production, collectively forming the backbone of China's energy supply system.

However, provincial disparities are notable. Guizhou and Henan, though included among the top producers, fall below the national average in production capacity. This imbalance suggests that local ecosystems in such provinces may bear disproportionately high environmental pressures relative to their output, intensifying the negative impacts of coal mining on land, water, and air quality.

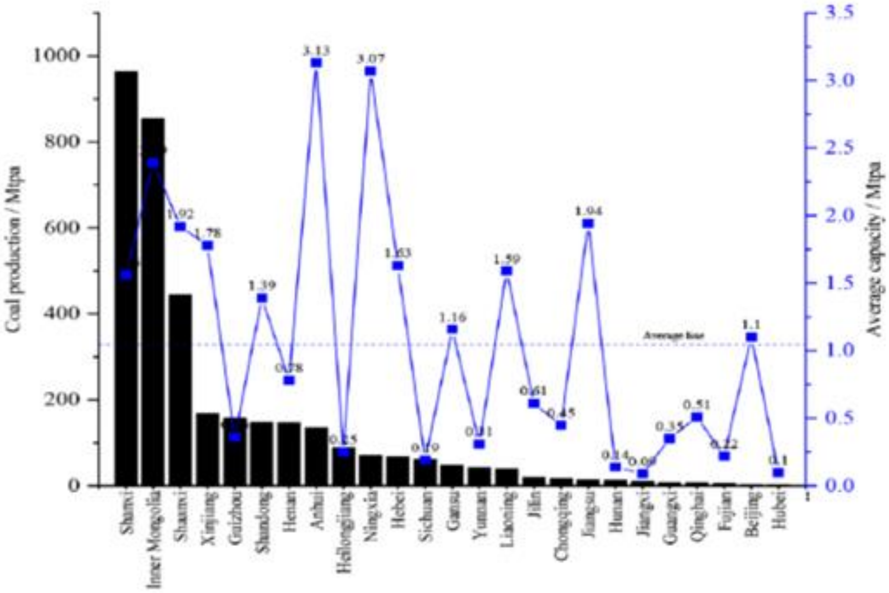

Fig. 2 Coal production capacity by province.

2.2. Coal mining methods and scale in China

Due to China's unique national conditions and geographical features, coal mining is predominantly underground, accounting for 87% of total production. China has a total of 3,292 underground coal mines, representing 97.6% of all coal mines and contributing 87% of production capacity.3 Although open-pit coal mines account for a small proportion, their significant production capacity means their environmental impact must also be taken into consideration.

2.3. Greenhouse gas emissions

Methane (CH_4) is a potent greenhouse gas (GHG), and China is the world's largest contributor to anthropogenic CH_4 emissions, accounting for approximately 15% of total CH_4 emissions in 2014. Coal mine methane (CMM) represents China's largest methane emission source, releasing 25 million metric tons (Mt) in 2018—accounting for 42% of China's total human-induced CH4 emissions. Notably, the abandoned coal mines have been the second-largest CMM source since 1999, contributing 16% by 2022. 4

3. Results

Using the aforementioned academic sources, this paper summarizes and analyzes the potential environmental impacts of coal mining, including ground subsidence, water resource depletion and pollution, and effects on the atmosphere.

3.1. Land Resource Degradation and Ground Subsidence

The impact of coal mining on surrounding land resources and ground subsidence primarily manifests as land resource degradation and ground subsidence. Coal mining occupies vast amounts of land resources, disrupting existing land ecosystems and causing extensive ecological damage. Land resource destruction and ground subsidence adversely affect surrounding economic and social activities. For instance, coal mining may occupy farmland, hindering the sustainable development of agriculture and forestry. Simultaneously, ground subsidence can damage buildings, roads, and other infrastructure, increasing socioeconomic costs.5 Additionally, toxic compounds such as heavy metals, radioactive elements, polycyclic aromatic hydrocarbons (PAHs), and other organic pollutants are also released into the environment, which will similarly impact ecosystems.6 Wang et al. (2017) revealed the vegetation damage and landscape fragmentation trends caused by open-pit mining through a study of the Pingshuo open-pit coal mine.7

3.2. Changes in groundwater levels.

The impact of coal mining on groundwater levels primarily manifests as lowering and depletion. During coal extraction, continuous pumping of groundwater is required to ensure safe production within mines. This pumping activity causes groundwater levels to drop, potentially leading to complete depletion.8 Lowering groundwater levels may diminish water resources in surrounding areas, impacting agricultural and industrial production. Additionally, declining groundwater levels can trigger surface soil subsidence, leading to geological hazards such as land subsidence and ground collapse.8

Coal mining may further deplete and reduce groundwater resources, impacting water supply and the ecological environment in surrounding areas.9The depletion of groundwater resources can lead to insufficient surface water supply, affecting agricultural, industrial, and other production activities. It can also disrupt the balance of aquatic ecosystems, damage natural habitats, and result in ecological degradation and reduced biodiversity.

Groundwater quality deterioration. The impact of coal mining on groundwater quality primarily manifests as contamination from mine wastewater, coal dust, coalbed methane, and other factors, leading to degraded groundwater quality. Host rock layers often contain pyrite (FeS_2), which upon exposure to air and water undergoes oxidation and chemical reactions to form sulfuric acid, rendering the drainage highly acidic.10This pollution contaminates rivers, lakes, and groundwater with extreme toxicity, capable of killing all aquatic life and rendering water bodies unusable for extended periods. Additionally, coal mine drainage typically contains high concentrations of suspended solids, sulfates, chlorides, and other substances, resulting in salinized water unsuitable for drinking or irrigation.

3.3. Climate Change and Dust Pollution

The environmental impacts of coal mining extend significantly to the atmosphere, with two primary manifestations: climate change and dust pollution. During mining operations, large quantities of coal dust, particulate matter, and exhaust gases are released, directly degrading local air quality and posing risks to public health. Dust emissions not only affect nearby residents but also contribute to the regional spread of particulate matter, which exacerbates urban air pollution problems.

On a broader scale, coal mining intensifies climate change by emitting substantial amounts of greenhouse gases, including carbon dioxide and methane. These gases accumulate in the atmosphere, accelerating global warming and disrupting natural processes such as precipitation patterns and climate variability [1]. Figure 3 (if inserted here) could illustrate trends in greenhouse gas emissions from coal mining activities, highlighting the long-term contribution of coal to anthropogenic climate forcing.

In addition to direct emissions, coal gangue piles represent a secondary but serious pollution source. Containing residual coal and pyrite, these piles are highly susceptible to spontaneous combustion. Once ignited, they release toxic and harmful gases—including sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), and further greenhouse gases—that persistently degrade air quality. The combination of direct emissions during mining and secondary pollution from waste piles underscores coal mining's multi-dimensional threat to atmospheric systems and climate stability.

4. Discussion

4.1. Summary of key findings

Coal remains an indispensable part of China's energy mix, accounting for the majority of the country's electricity generation [1] and serving as the primary driver of its methane emissions [2-4]. The key findings of this study are threefold. First, underground mining leads to land subsidence and geomorphic deformation, which in turn affect regional hydrological conditions and land use. Second, water resource damage is particularly severe: groundwater levels often decline [5-8], and acid mine drainage results in sulfate and heavy metal pollution that seriously threatens aquatic ecosystems. Third, coal mining produces large amounts of dust, exhaust gases, and greenhouse gases, contributing to air pollution and exacerbating global climate change [9-13].

4.2. Comparison with Previous Studies

The findings of this study are broadly consistent with previous research on coal mining's environmental impacts. For example, Liu et al. [13] confirmed that spontaneous combustion of coal gangue releases toxic gases such as SO_2, CO, and NO_x, which aligns with this study's observation of severe air pollution. Similarly, the groundwater depletion identified here corresponds to earlier studies that highlighted declining water tables due to continuous dewatering during mining operations [9]. However, this research adds new insights by illustrating the combined effects of surface subsidence and soil degradation, which have often been examined separately in prior work.

4.3. Implications of the Findings

Given the complexity and far-reaching impacts of coal mining, future studies should adopt a multi-dimensional approach. First, field-based monitoring is essential to capture real-time changes in groundwater levels, soil quality, and atmospheric pollutants. Second, longitudinal studies are needed to link environmental degradation with socio-economic impacts, thereby providing a holistic understanding of mining sustainability. Finally, research should explore innovative remediation techniques—such as bio-remediation and carbon capture—as well as renewable energy alternatives that can reduce the ecological footprint of coal mining and accelerate the transition to low-carbon development.

4.4. Limitations of the Study

This study concludes that while coal remains a critical energy source in China, its extraction imposes significant environmental costs, including land subsidence, groundwater depletion and contamination, and severe air pollution. These impacts highlight the urgent need for improved environmental governance and the adoption of sustainable mining technologies. Only through integrated management—combining stricter regulation, technological innovation, and ecological restoration—can coal mining's environmental footprint be effectively reduced while supporting the nation's energy needs.4.5 Suggestions for Future Research

In view of the complexity and far-reaching impacts of coal mining development, it is necessary to conduct in-depth studies on its various environmental effects in order to provide a scientific basis for sustainable mining management and ecological restoration. Future research should incorporate field-based measurements to observe patterns and quantify pollutant emissions more accurately. Longitudinal studies assessing both environmental and socio-economic dimensions would provide a more comprehensive understanding of mining impacts. Moreover, exploring innovative remediation strategies and renewable energy alternatives could offer practical solutions for reducing the ecological footprint of coal mining.

5. Conclusion

This study demonstrates that coal mining in China, while ensuring energy supply and economic growth, generates significant environmental challenges. The main impacts include land degradation and surface subsidence caused by underground extraction, depletion and contamination of groundwater resources due to dewatering and acid mine drainage, and atmospheric pollution driven by coal dust, spontaneous combustion of coal gangue, and emissions of greenhouse gases such as CO_2 and CH_4. These findings highlight the multi-dimensional risks coal mining poses to ecosystems, water security, and climate stability.

The results also suggest that sustainable mining management is urgently needed. Stricter monitoring of groundwater quality, adoption of dust suppression and gangue reuse technologies, and improved treatment of acid mine drainage are critical to mitigating environmental damage. Furthermore, integration of advanced technologies such as carbon capture and storage (CCS) and methane utilization can help reduce greenhouse gas emissions, aligning coal mining practices with China's low-carbon transition goals.

Looking ahead, addressing the environmental impacts of coal mining requires coordinated efforts from policymakers, industry, and researchers. Field-based monitoring and longitudinal studies should be prioritized to provide accurate data for decision-making, while ecological restoration and renewable energy alternatives can play a key role in reducing long-term ecological costs. By advancing both regulatory and technological measures, China can move toward a more sustainable balance between energy security and environmental protection.

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