Phase Transformation and Carcinogenicity of Coal Combustion Particles from Xuan Wei: An In Vitro and In Vivo Study

Zheshen Han [a †], Jinhui Li [abc †], Wuyue Yu [c], Lung-Chi Chen [c], George D. Thurston [c *], Linwei Tian [a *]

a School of Public Health, LKS Faculty of Medicine, The University of Hong Kong, Hong Kong SAR.
b School of Public Health, University of Illinois Chicago, School of Public Health, Chicago, IL, USA.
c Department of Environmental Medicine, New York University School of Medicine, New York, NY, USA.

15 Name: Zheshen HAN (PhD)
Primary Supervisor: Prof. Linwei Tian

Background

- Xuan Wei, a county in Yunnan Province in southwest China, exhibits the highest female lung cancer mortality rate in China, attributed primarily to indoor coal combustion
- Evidence from epidemiological studies has shown that long-term exposure to indoor bituminous coal usage is associated with an increased risk of lung cancer and other respiratory diseases, such as COPD in Xuan Wei, China
- Chamosite has been considered associated with the lung cancer epidemic in Xuan Wei. Our preliminary studies also suggest that chamosite may undergo a phase change during bituminous coal's heating and combustion process

Objectives

- To evaluate the carcinogenicity of bituminous coal from Xuan Wei at different stages during the combustion process from the clay mineral perspective
- To investigate the toxicity and carcinogenic mechanisms of coal particles during combustion at varying temperatures may yield significant insights

Methods

- Bituminous coal collection and characterization:
  - ➢ 1) The regional domestic bituminous coals originate from C1 coal, were then divided into 4 groups based on the heating temperature, respectively: unheated room temperature (RT), 90 °C (most of the water evaporates), 250 °C (just before chamosite initiated phase transformation), and 550 °C (after chamosite finalized phase transformation). ;
  - ➢ 2) X-ray diffraction (XRD) was for mineral phases of powder samples; scanning electron microscopy (SEM) & energy-dispersive X-ray spectrometer (EDS) were for images.
- In vivo study:
  - ➢ BEAS-2B, an immortalized human bronchial epithelial cell line is used for malignant transformation and soft-agar assay after exposure to the coal samples.
- In vitro study:
  - ➢ C57/6J mice were under inhalation exposure of coal samples via oropharynx aspiration and gavage intervention of iron chelator. The lungs of the mice were dissected and weighed following the collection of bronchoalveolar lavage fluid (BALF).

Conclusion

- BEAS-2B cells exposed to coal particles exhibit anchorage-independent growth, indicating carcinogenic potential, particularly pronounced at 250°C, corresponding to temperature-induced chamosite transformations
- In vivo experiments involving C57BL/6J mice exposed to these particles reveal elevated inflammatory responses, with a dose-response relationship evident at higher concentrations and temperatures.
- The study reveals the potential hazardous impact of bituminous coal exposure in Xuan Wei on lung health. Chamosite in bituminous coal, particularly after being heated at 250°C, was notably more carcinogenic, potentially due to the original chamosite having higher iron activity before oxidation during phase transformation.
- These findings not only advance our understanding of coal-induced lung carcinogenesis but also highlight critical intervention points for public health strategies aimed at reducing the lung cancer burden in coal-dependent regions like Xuan Wei. This research supports the need for transitioning to cleaner fuels and improving indoor air quality to protect vulnerable populations from the deleterious health effects of coal smoke.

Results

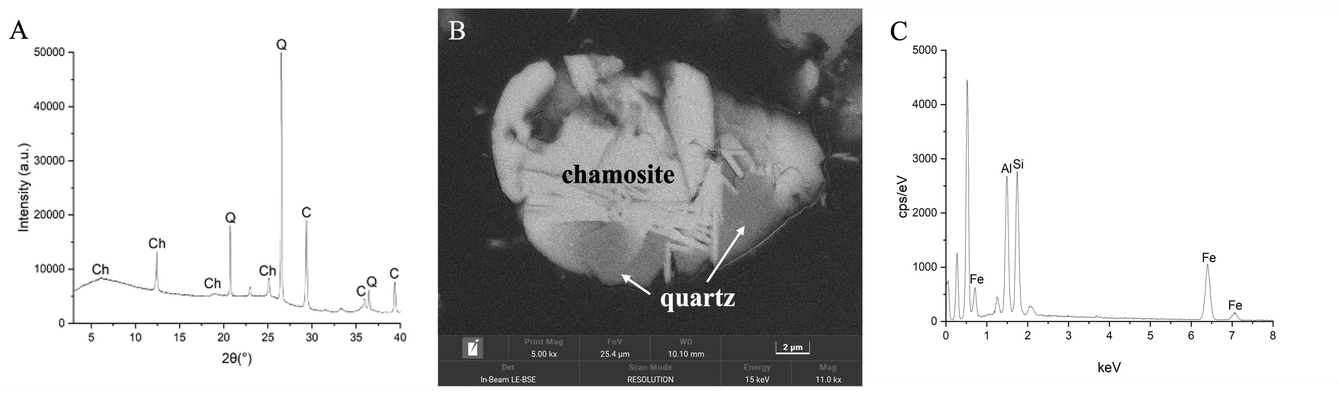

Figure 1 Characterization of C1 coal powders. (A) X-ray powder diffraction pattern of C1 coal. (B) Morphology of cross-sectional surface polishing C1 coal under SEM back-scattered electron (BSE) mode. (C) Chemical composition of chamosite. Ch: chamosite. Q: quartz. C: calcite.

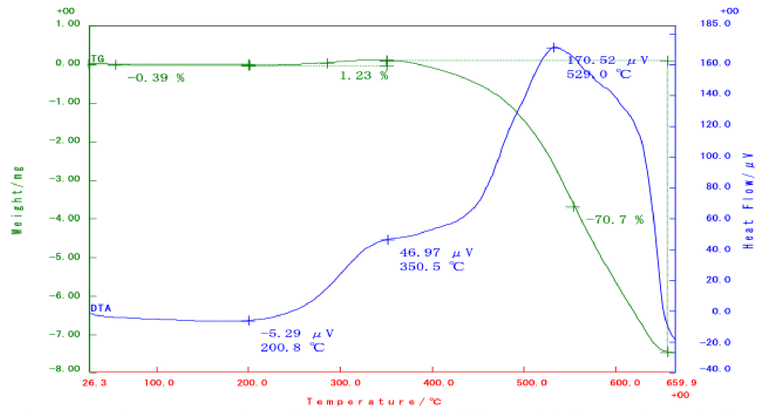

Figure 2 Thermogravimetric (green) and differential thermal analysis (blue) of C1 coal powders from room temperature to 660 °C.

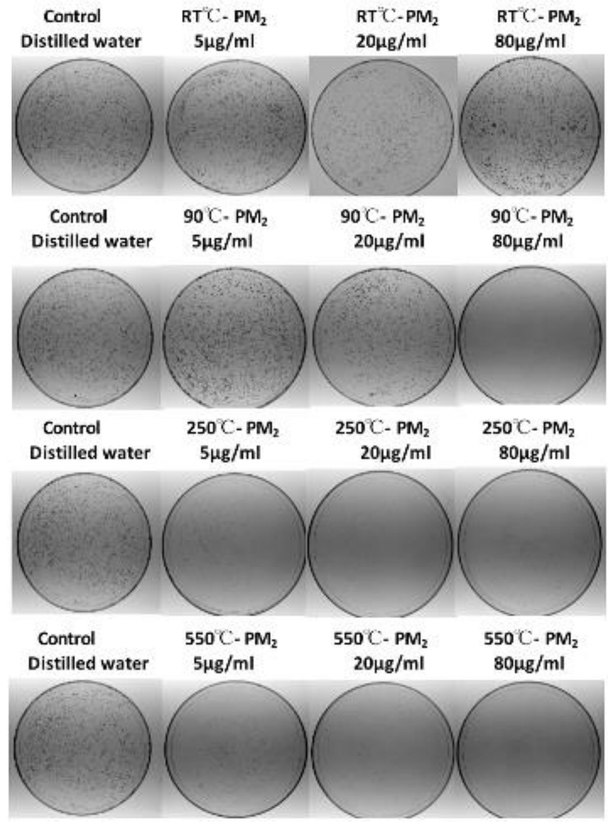

Figure 3. The positive colony formations after 12-week post exposure of Xuan Wei 250°C-PM_2 and 550°C-PM_2 coal samples on soft-agar in BEAS- 2B cell lines. A) Colonies formed on the soft-agar plate.

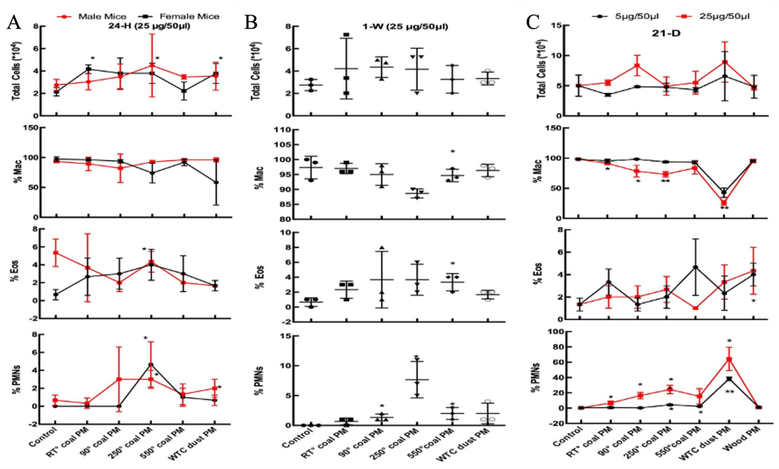

Figure 4. Bronchoalveolar lavage fluid (BALF) cell counts after particle exposure. (A) Acute exposure (24-H) for male and female mice. (B) Acute exposure (1-Week) for female mice. (C) Sub-chronic exposure (21-Day) for female mice. Eos, eosinophils. PMNs, polymorphonuclear leukocytes. Mac, macrophages. (* P < 0.05)

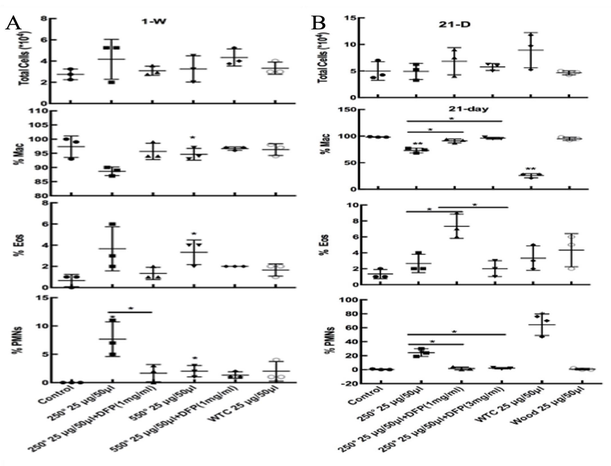

Figure 5. Bronchoalveolar lavage fluid (BALF) cell counts after Xuan Wei, WTC PM exposure with or without DFP gavage intervention. (A) Acute Xuan Wei PM exposure (1-week) and DFP gavage intervention. (B) Sub-chronic Xuan Wei PM exposure (21-Day) and DFP gavage intervention. PMNs, polymorphonuclear leukocytes. Mac, macrophages. (* P < 0.05)

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