Abstract

Coal Workers' Pneumoconiosis (CWP), commonly known as black lung disease, is a progressive occupational lung disease caused by prolonged exposure to coal mine dust. Its pathogenesis involves oxidative stress, inflammation, cellular damage, and fibrosis. Despite recognized health risks, the role of bioavailable iron (BAI) in CWP remains understudied, with no prior data from India. This study investigates the impact of BAI in respirable coal dust (BAI-RCD) on CWP pathogenesis using in vitro and in vivo models.

Seventy-seven coal samples were collected from ten mining regions across central India, with BAI concentrations ranging from 275 to 9065 mg/kg. Advanced analytical techniques were employed to assess elemental composition, focusing on BAI. In vitro experiments using A549 alveolar epithelial and U937 macrophage cell lines demonstrated significant ($p < 0.001$) dose-dependent cytotoxicity, oxidative stress (elevated NADPH, MPO, LPO, PC), and inflammatory responses (increased cytokines TGF-β1, IL-1β, TNF-α, MCP-1, IL-6) upon exposure to BAI-RCD. DNA damage (8-OHdG) was also significantly elevated.

In vivo studies using male Wistar rats exposed to 10, 20, and 40 mg/m³ of BAI-RCD for 30 and 60 days revealed histopathological alterations, including epithelial necrosis, septal and perivascular edema, alveolar macrophage hypertrophy, and coal-laden macrophages. Increased exposure led to bronchiolar epithelial necrosis, collagen deposition, and decreased Clara and goblet cells, along with heightened neutrophil infiltration.

Findings indicate that BAI significantly exacerbates oxidative stress and inflammation, contributing to lung tissue damage and fibrosis, key events in CWP progression. The study underscores BAI as a critical determinant of coal dust-induced toxicity, emphasizing the need for stringent monitoring and regulation of BAI levels in coal mines to mitigate health risks. These findings highlight the necessity of safety measures and exposure limits to protect coal workers from BAI-associated pulmonary toxicity.

Keywords

Coal mining, Occupational health, Coal Workers' Pneumoconiosis, Bioavailable iron, Respirable coal dust, Oxidative stress, Lung fibrosis, Cytotoxicity, Histopathology