



Assessment Of Health Risks Associated With Long-Term Coal Mine Dust Exposure, Including A Specific Study Of Fungal Impact On Coal Miners Of The Opencast Coal Mine, Chandrapur, India.

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Abstract: The extensive coal mining activities in Chandrapur, Maharashtra, have led to significant environmental degradation and pose serious health risks to coal miners. This study assessed the health impacts of long-term coal dust exposure, with a specific focus on the fungal species present in the Pauni-II Expansion Opencast Coal Mine environment and their potential effects on workers. Using air and skin samples, fungal species were isolated and identified from miners and the surrounding environment. Petri plates containing Sabouraud Dextrose Agar (SDA) and Potato Dextrose Agar (PDA) were used to collect airborne fungi at various distances (0m, 100m, 300m, 500m) from the mine entrance, while skin samples were collected from miners exposed to coal dust. A total of 12 fungal genera were identified, with *Aspergillus* (19.2%), *Candida* (19.2%) and *Trichophyton* (17.5%) being the most prevalent in air samples. Skin samples revealed a predominance of *Candida species* (86.7%), indicating potential risks for skin infections among miners. Respiratory health data collected through an online survey of 80 miners highlighted the prevalence of symptoms such as persistent coughing (60%), asthma exacerbation (38.75%) and reduced lung function (43.75%). The findings underscore the urgent need for improved ventilation, protective equipment and regular health monitoring to mitigate the occupational health risks in coal mining. These results contribute valuable insights into the fungal hazards in mining environments and provide evidence-based recommendations for enhancing worker safety protocols.

Index Terms - Coal Mines, Mining Industry, Fungal Impact, Respiratory Issues, Preventive Measures, Environmental Health, Occupational Health

I. INTRODUCTION

Chandrapur, commonly known as the "Black Gold City," is a major coal-producing region in Maharashtra, India, with over 30 active mines managed by Western Coalfields Limited (WCL) (Greenpeace - Padmapur Coal Mine in Chandrapur, n.d.). While coal mining significantly contributes to the local economy through employment and energy production, it also brings considerable environmental and health challenges. The environmental degradation caused by coal mining in Chandrapur includes deforestation, loss of wildlife habitat and increased human-animal conflicts. This activity also contributes to severe air, water and soil pollution. Air pollution is particularly concerning, characterized by elevated levels of particulate matter (PM), sulfur dioxide (SO₂) and nitrogen oxides (NO_x). PM_{2.5} particles, which can penetrate deep into the

lungs, pose serious respiratory and cardiovascular health risks (Gawande *et al.*, 2016; Ruidas & Pal, 2022). In Chandrapur, the average PM_{2.5} levels often exceed the World Health Organization's (WHO) safe limits (What Are the WHO Air Quality Guidelines?, n.d.; Chandrapur Air Quality Index (AQI), n.d.), placing the region among the poorest performers in global air quality indices. Its Air Quality Index (AQI) frequently reaches "unhealthy" levels. Additionally, the area experiences high UV index levels, particularly during summer, increasing the risk of skin diseases and other health issues related to prolonged sun exposure. The health impacts of coal mining extend to respiratory diseases, such as Coal Workers' Pneumoconiosis (CWP), Chronic Obstructive Pulmonary Disease (COPD), asthma, silicosis, bronchitis and lung cancer (Laney & Weissman, 2014). Long-term exposure to pollutants like PM_{2.5}, SO₂ and NO_x exacerbates these conditions, contributing to higher morbidity and mortality rates among miners and local communities. Furthermore, coal mines serve as reservoirs for various microorganisms, including pathogenic bacteria and fungi, which present additional health risks. Notable bacteria include *Staphylococcus aureus*, *Streptococcus pyogenes*, *Pseudomonas aeruginosa* and *Mycobacterium tuberculosis*. Fungal species, such as *Aspergillus fumigatus* and *Candida albicans*, are also prevalent and known to cause serious infections (Akimbekov *et al.*, 2022; Tulsian *et al.*, 2017.). While the economic benefits of coal mining are significant, the environmental and health risks it poses are severe. Addressing these challenges requires effective mitigation measures, such as improved occupational health practices, environmental restoration efforts and stricter pollution control measures (Kerfahi *et al.*, 2022). In light of these challenges, this study aims to investigate the prevalence and diversity of airborne fungal species in the coal mining environment, assess their potential health impacts on miners and explore the relationship between prolonged dust exposure and respiratory conditions. Through air and skin sample analyses, combined with an online survey of miners, this study seeks to identify specific fungal species associated with occupational health hazards and provide data-driven recommendations to improve workplace health and safety protocols..

II. RESEARCH METHODOLOGY

A two-phase study was conducted to investigate respiratory diseases, with a particular emphasis on airborne fungi within coal mining environments. The study aimed to identify airborne fungal species, assess their potential health impacts on coal miners and correlate prolonged dust exposure with respiratory conditions. To identify research gaps and better understand the potential health risks of respiratory diseases among coal miners, a comprehensive review of relevant literature was performed. This review utilized databases such as PubMed, Google Scholar, Web of Science and Embase, focusing on respiratory diseases like pneumonia, asthma, bronchitis, chronic obstructive pulmonary disease (COPD) and lung cancer. The literature review provided a foundational understanding of the respiratory conditions commonly associated with coal mining and helped frame the scope of the field investigation..

The first phase of the field study was carried out at the Pauni-II Expansion Opencast Coal Mines in Chandrapur, Maharashtra. This phase centered on the identification of airborne fungi through the open plate (passive) sampling method. Petri plates containing Sabouraud Dextrose Agar (SDA) (n=8) and Potato Dextrose Agar (PDA) (n=8) were used for fungal isolation. Air samples were collected at various distances from the mine entrance (0 m, 100 m, 300 m, 500 m) by exposing the plates to ambient air for 5 to 10 minutes, as per the passive sampling technique (Viani *et al.*, 2020). In addition to air sampling, dust samples were collected from the skin surfaces of coal miners exposed to coal dust. Sterile swabs were used to gather dust from the skin, which was then inoculated onto SDA and PDA plates. All these plates were incubated at room temperature for 4 to 5 days to allow for fungal growth. Fungal species were identified based on spore morphology, septation and methods of spore production. The identification process was further confirmed using lactophenol cotton blue staining to observe microscopic characteristics.



Figure. 1: PDA and SDA plates at various distances from the entrance of Pauni-II Expansion Opencast Coal Mine. (0m, 100m, 300m, 500m)

The second phase was conducted in order to complement the experimental data. An online survey was distributed to 80 coal mine workers aged between 22 and 58 years (mean age: 40 years) to assess respiratory health issues related to coal dust exposure. The survey collected demographic information, work details, respiratory symptoms and safety concerns. The sample predominantly consisted of male workers (95%), representing both underground and opencast mine operations.

Most respondents (56.25%) were involved in mechanical work, with 35% residing in Chandrapur and 65% from surrounding areas. Nearly all participants (97.5%) reported undergoing regular medical check-ups, underscoring the importance of health monitoring in this high-risk occupation. The survey was administered both in-person and online, ensuring broad representation of the workforce. The questionnaire featured a balanced mix of closed and open-ended questions to capture comprehensive insights into the miners' respiratory health and working conditions.

The results from the survey were integrated with data from the literature review and field investigation, providing a holistic understanding of the health impacts of coal mining. These findings informed the identification of specific fungal species associated with occupational hazards and supported recommendations for improving health and safety protocols in coal mining environments.

III. RESULTS AND DISCUSSION

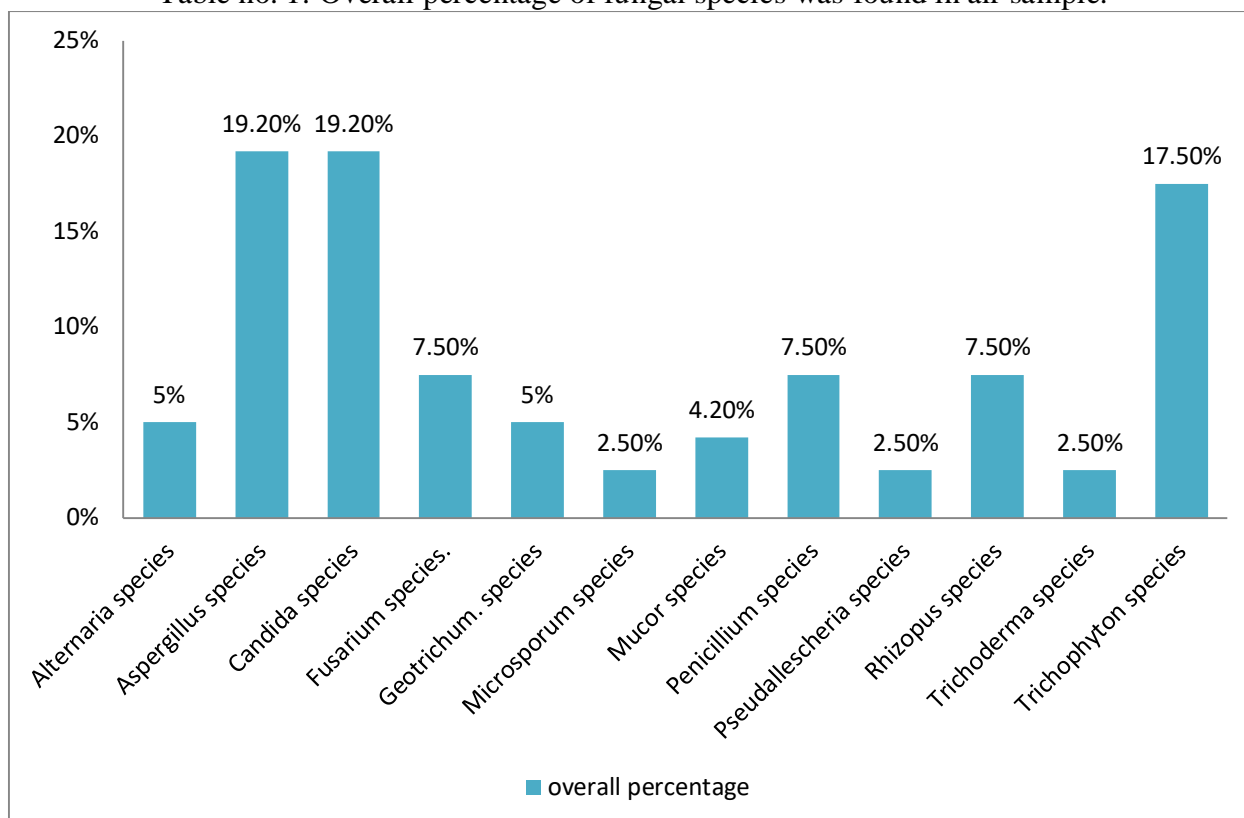
Our investigation into fungal diversity within the Pauni-II Expansion Opencast Coal Mine and its workforce identified 12 distinct fungal genera. Species were characterized through morphological analysis and colony traits, utilizing both environmental air samples and swab samples taken from workers

3.1 Fungal Ecology and Occupational Exposure

3.1.1 Fungal Distribution in Environmental Samples:

Air sampling was conducted at four distinct locations at distances of 0m, 100m, 300m and 500m from the mine entrance. Across these locations, a diverse array of fungal species was identified. The most prevalent genera in the air samples were *Aspergillus species* (19.2%) and *Candida species* (19.2%), followed by *Trichophyton species* (17.5%). Other detected fungi included *Fusarium species* (7.5%), *Penicillium species* (7.5%), *Rhizopus species* (7.5%), *Alternaria species* (5%), *Geotrichum species* (5%), *Mucor species* (4.2%), *Microsporum species* (2.5%), *Pseudallescheria species* (2.5%) and *Trichoderma species* (2.5%), (Table no. 1) some of which are commonly found in same settings around the globe, like *Aspergillus species*, *Mucor species*, *Penicillium species*, *Trichoderma species* (Rdzanek *et al.*, 2015). This also aligns with previous studies highlighting these genera as common occupational fungi in industrial settings (Viegas *et al.*, 2018)

Table no. 1: Overall percentage of fungal species was found in air sample.



It was also observed that fungal counts increased at greater depths, specifically at 300m and 500m, suggesting higher fungal exposure for miners working in these areas. Both Potato Dextrose Agar (PDA) and Sabouraud Dextrose Agar (SDA) successfully isolated various fungal species, though slight variations in species detection were observed depending on the sampling location and the type of media used

3.1.2 Fungal Distribution in Worker Swab Samples:

The increased fungal spore counts at deeper mine locations (300m and 500m) suggest a gradient of exposure, with workers in these areas facing potentially higher risks. For analysis a total of 80 swab samples were collected from coal miners exposed to coal dust. Analysis of these swabs revealed a more limited range of fungal species compared to environmental samples, with a striking predominance of *Candida species* (86.7%) on skin surfaces. Additionally, *Aspergillus species* were detected in 8.3% of the swab samples, while *Trichophyton species* were present in 5% of the samples. This distribution differs from other regions, where *Trichophyton* was the most common species (79%) and *Candida* was found in 60% of cases (Shams-Ghahfarokhi *et al.*, 2014). These findings indicate a higher prevalence of *Candida* on miners' skin compared to other fungal species, likely due to the humid and dust-rich environment in which they work. The presence of *Aspergillus* and *Trichophyton* species along with *Candida* species on the skin further indicates potential health risks related to skin infections among the miners (Sarma *et al.*, 2008; Shams-Ghahfarokhi *et al.*, 2014)

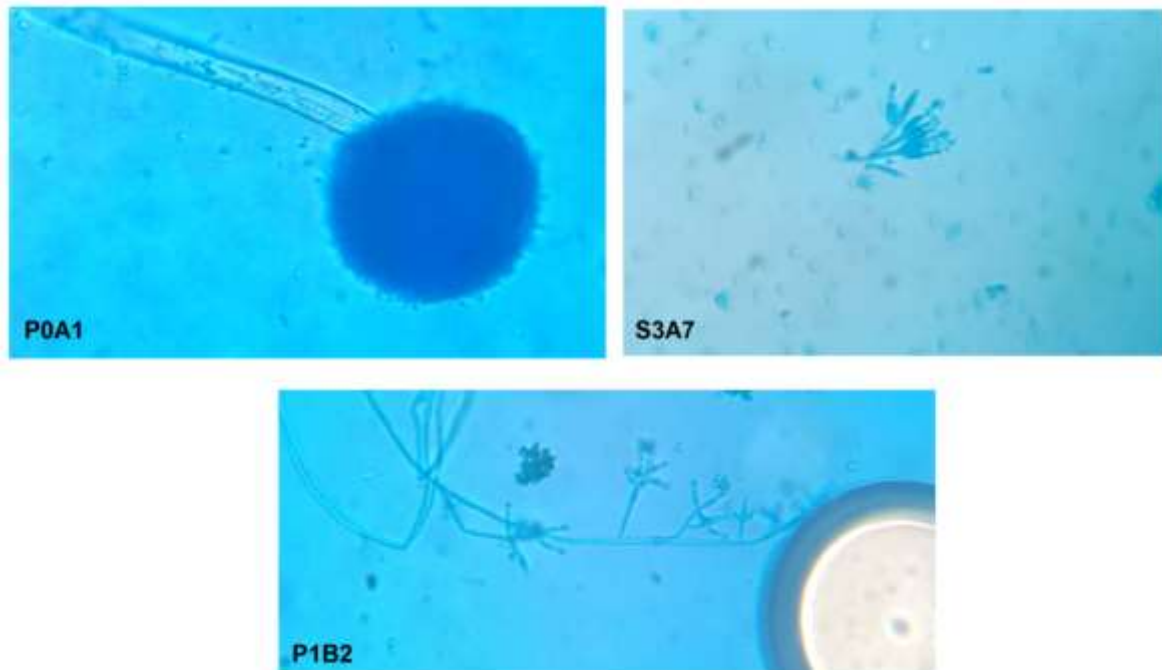


Figure 2: P0A1, S3A7 (both *Aspergillus species*), P1B2 (*Penicillin species*) showing different types of conidial structures.

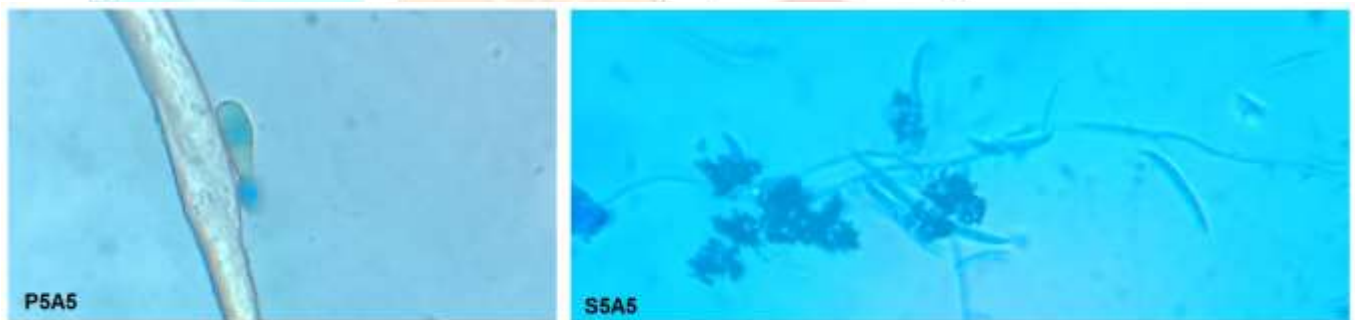


Figure 3: P5A5 (*Alternaria species*), S5A5 (*Fusarium species*) showing different types of spores.

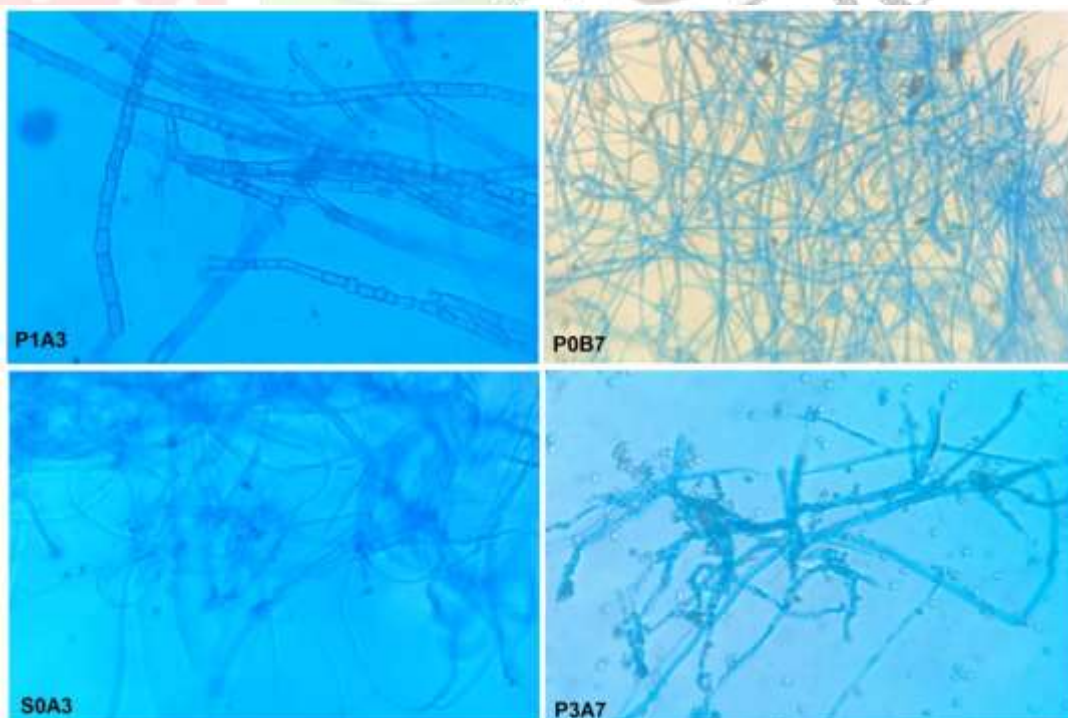


Figure 4: P1A3 (*Tricoderma species*), P0B7 (*Trichophyton species*), S0A3 (*Mucor species*), P3A7 (*Pseudallescheria species*) showing different types of hyphae.

3.2 Occupational Health Survey: Demographic and Health Profile of Coal Mine Workers:

The study involved a survey of 80 participants (coal mine workers) aged 22-58 years, with a mean age of 40 years, primarily comprising middle-aged individuals. The largest age group was 30-40 years (45%), followed by the 50-60 age groups (32.5%). Participants aged 20-30 years accounted for 21.25%, while only 1.25% was between 40-50 years. This distribution highlights a significant representation of middle-aged workers who may have varying susceptibility to coal dust exposure and airborne fungal infections.

The sample was predominantly male (95%), reflecting the demographic of the coal mining workforce. Regarding living locations, 35% of participants resided in Chandrapur, while 65% were from surrounding areas, which may affect their exposure to environmental hazards. Job distribution showed that 56.25% were engaged in mechanical work, while other roles, including drivers, administrative workers and supervisors, accounted for smaller proportions. Notably, 97.5% of participants reported regular medical check-ups, emphasizing the importance of health monitoring in this high-risk occupation. These findings provide insight into the workforce's demographic and occupational factors that influence their exposure to coal mining-related health risks.

The analysis of the participants' medical histories revealed several key health issues related to their occupational environment. The table no.2 outlines the prevalence of various occupational health issues:

Table 2: Prevalence of Occupational Health Issues and Symptoms among Coal Mine Workers

Health Issues	Count	Percentage (%)
Discomfort due to humidity during working hours.	49	61.25
Discomfort due to high temperature during working hours	48	60
Discomfort due to high noise levels during working hours	56	70
Health affected due to dust	76	95
Persistent coughing	48	60
Wheezing	7	8.75
Shortness of breath	14	17.5
Chronic bronchitis	4	5
Worsening of asthma	31	38.75
Dermatitis or skin rashes	13	16.25
Itching or redness on exposed skin areas	64	80
Eye and Nasal Irritation	43	53.75
Fungal Infections	36	45
Chronic Health Conditions	34	42.5
Reduced Lung Function	35	43.75

3.3 Health Implications of Fungal Exposure

The health survey results reveal a concerning pattern of respiratory and dermatological issues among miners. Persistent coughing (60%), shortness of breath (17.5%) and asthma exacerbation (38.75%) are prevalent, correlating with the presence of airborne fungi, particularly *Aspergillus* and *Trichophyton* species (Maturu & Agarwal, 2015; Sisodia & Bajaj, 2024). These symptoms are consistent with occupational respiratory diseases such as allergic bronchopulmonary aspergillosis (ABPA) and hypersensitivity pneumonitis (Sisodia & Bajaj, 2024). Given that *Aspergillus* is a known allergen and pathogen, prolonged exposure to both fungal spores and coal dust in Chandrapur increases the risk of ABPA, recurrent asthma exacerbations and other complications like chronic pulmonary aspergillosis, invasive aspergillosis and emphysema (Agarwal, 2009; Lowes *et al.*, 2015).

Dermatological issues, such as itching or redness (80%) and dermatitis (16.25%), stem from fungal colonization and environmental factors. The prevalence of *Trichophyton rubrum*, the primary agent of dermatophytosis, in both air (17.5%) and skin samples (5%) supports this risk (Petrucci *et al.*, 2020). This fungal species is a significant cause of superficial infections like ringworm, especially in harsh, humid working conditions (Gnat *et al.*, 2019; Khurana *et al.*, 2019). Although dermatophytes generally cause superficial infections of keratinized tissues, there are increasing reports of deeper invasions in immunocompromised individuals, causing infections that spread to lymph nodes, the brain and bloodstream (Lanternier *et al.*, 2013).

3.4 Environmental Factors and Occupational Health

The reported discomfort reported by mine workers, due to high noise levels (70%) and elevated temperatures (60%) which leads to stress, highlights the multifaceted nature of occupational hazards in coal mining. In Chandrapur, these environmental stressors, combined with high fungal exposure and coal dust inhalation, can create a complex risk profile for miners. The synergy of these factors can lead to health issues and potentially compromises immune function, contributing to both respiratory and dermatological complications. Fungal spores flourish in environments with high dust levels and humidity (Mousavi *et al.*, 2016). These conditions are similar to those found in the Chandrapur mining area. The detection of fungal spores such as *Aspergillus species* (19.2% in air) and *Trichophyton species* (17.5% in air) further contributes to the risk profile in Chandrapur mining,

Future research on the effects of coal dust exposure on DNA damage and telomere length could provide insights into the variability of biological responses among Chandrapur miners (Miranda-Guevara *et al.*, 2023). Oxidative DNA damage and its link to karyocyte apoptosis, which can reduce lymphocyte populations, have been observed as risks associated with coal dust exposure (Chen *et al.*, 2024). Genotoxic effects, such as micronuclei formation, nucleoplasmic bridges, and nuclear buds, have also been documented in exposed workers (Sinitsky *et al.*, 2016). Toxic metals present in coal dust are known to cause DNA damage through oxidative mechanisms, leading to complex cellular responses (Matzenbacher *et al.*, 2017). Additionally, inadequate use of protective equipment has been associated with increased occupational risks, suggesting the need for effective safety protocols (Kvitko *et al.*, 2012). These studies imply potential health risks for miners in Chandrapur, who may experience similar effects despite long-term exposure, though they may remain undiagnosed, highlighting variability in biological responses across mining environments. Our findings underscore the need for comprehensive occupational health strategies in coal mining. The high prevalence of fungal species, particularly in deeper mine locations, calls for improved ventilation systems and frequent air quality monitoring. Additionally, the use of personal protective equipment (PPE) designed for both respiratory and skin protection is crucial, given the high rates of dermatological and respiratory symptoms observed in this study. Advanced PPE could help mitigate exposure to fungal spores and coal dust, especially in high-risk areas within the mines (Agarwal, 2009; Mousavi *et al.*, 2016).

Regular medical surveillance, as reported by 97.5% of participants, is a positive practice that should be continued and enhanced. However, despite routine check-ups, the high prevalence of health issues, particularly those related to fungal exposure, suggests a need for more targeted screenings, such as specific testing for fungal-related conditions like ABPA, candidiasis and dermatophytosis (Sisodia & Bajaj, 2024; Wächtler *et al.*, 2012). Additionally, interventions to control temperature, humidity and noise levels in mining environments are essential to reduce occupational health risks. The establishment of on-site health clinics offering both preventive and acute care would provide miners with timely access to medical services, improving overall health outcomes.

To improve occupational health in coal mining, we recommend enhancing ventilation systems to reduce fungal and dust exposure, improving personal protective equipment and conducting regular health check-ups focused on respiratory, dermatological and mental health. Education programs on health risks, strategies to control environmental factors and the establishment of on-site health clinics are crucial. Additionally, targeted interventions for older miners and further research, particularly longitudinal studies, are needed to assess long-term health impacts

Limitations of this study include the small sample size and the lack of control for confounding factors such as tobacco use or diet. Future studies should involve larger, more diverse samples and explore healthcare access, with longitudinal designs to better understand the long-term effects of coal mining on health

IV. CONCLUSION

The Chandrapur coal mining environment presents significant occupational health risks due to the combined impact of fungal exposure and coal dust inhalation. Our study identified a high prevalence of allergenic and pathogenic fungi such as *Candida*, *Aspergillus* and *Trichophyton* in air and skin samples, contributing to respiratory and dermatological conditions among miners. Survey results highlighted widespread respiratory issues, mental health concerns and adverse working conditions, emphasizing the need for immediate intervention. To address these risks, we recommend enhancing ventilation systems, improving personal protective equipment and establishing regular, comprehensive health check-ups. Worker education programs on health risks and protective practices are also essential. Furthermore, strategies to control environmental factors like temperature and humidity should be implemented and on-site clinics should offer

both acute and preventive care. Targeted interventions for older miners and further research on the long-term health impacts are necessary.

REFERENCES

- Akimbekov, N. S., Digel, I., Tastambek, K. T., Marat, A. K., Turaliyeva, M. A., & Kaiyrmanova, G. K. (2022). Biotechnology of Microorganisms from Coal Environments: From Environmental Remediation to Energy Production. *Biology*, 11(9), 1306. <https://doi.org/10.3390/biology11091306>
- Allergic bronchopulmonary aspergillosis. *Chest*, 135(3), 805–826. <https://doi.org/10.1378/chest.08-2586>
- Chandrapur Air Quality Index (AQI): Real-Time Air Pollution. (n.d.). Retrieved October 21, 2024, from <https://www.aqi.in/in/dashboard/india/maharashtra/chanda/chandrapur>
- Chen, H., Ding, X., Zhang, W., & Dong, X. (2024). Coal mining environment causes adverse effects on workers. *Frontiers in Public Health*, 12, 1368557. <https://doi.org/10.3389/fpubh.2024.1368557>
- Gawande, U., Khanvilkar, A., Kadam, S., & Salvitthal, G. (2016). Effects of ambient air pollution on respiratory health of adults: Findings from a cross-sectional study in Chandrapur, Maharashtra, India. *International Journal of Research in Medical Sciences*, 1546–1557. <https://doi.org/10.18203/2320-6012.ijrms20161226>
- Gnat, S., Łagowski, D., Nowakiewicz, A., & Zięba, P. (2019). The host range of dermatophytes, it is at all possible? Phenotypic evaluation of the keratinolytic activity of *Trichophyton verrucosum* clinical isolates. *Mycoses*, 62(3), 274–283. <https://doi.org/10.1111/myc.12876>
- Greenpeace—Padmapur Coal Mine in Chandrapur. (n.d.). Retrieved January 7, 2024, from <https://media.greenpeace.org/archive/Padmapur-Coal-Mine-in-Chandrapur-27MZIFI9ZVP1.html>
- Kerfahi, D., Newsham, K. K., Dong, K., Song, H., Tibbett, M., & Adams, J. M. (2022). Enduring legacy of coal mining on the fungal community in a High Arctic soil after five decades. *Pedosphere*, 32(5), 698–706. <https://doi.org/10.1016/j.pedsph.2022.06.001>
- Khurana, A., Sardana, K., & Chowdhary, A. (2019). Antifungal resistance in dermatophytes: Recent trends and therapeutic implications. *Fungal Genetics and Biology: FG & B*, 132, 103255. <https://doi.org/10.1016/j.fgb.2019.103255>
- Kvitko, K., Bandinelli, E., Henriques, J. A. P., Heuser, V. D., Rohr, P., Silva, F. R. da, Schneider, N. B., Fernandes, S., Ancines, C., & Silva, J. da. (2012). Susceptibility to DNA damage in workers occupationally exposed to pesticides, to tannery chemicals and to coal dust during mining. *Genetics and Molecular Biology*, 35, 1060–1068. <https://doi.org/10.1590/S1415-47572012000600022>
- Laney, A. S., & Weissman, D. N. (2014). Respiratory Diseases Caused by Coal Mine Dust. *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine*, 56(0 10), S18–S22. <https://doi.org/10.1097/JOM.0000000000000260>
- Lanternier, F., Pathan, S., Vincent, Q. B., Liu, L., Cypowyj, S., Prando, C., Migaud, M., Taibi, L., Ammar-Khodja, A., Stambouli, O. B., Guellil, B., Jacobs, F., Goffard, J.-C., Schepers, K., Del Marmol, V., Boussofara, L., Denguezli, M., Larif, M., Bachelez, H., ... Puel, A. (2013). Deep dermatophytosis and inherited CARD9 deficiency. *The New England Journal of Medicine*, 369(18), 1704–1714. <https://doi.org/10.1056/NEJMoal208487>
- Lowes, D., Chishimba, L., Greaves, M., & Denning, D. W. (2015). Development of chronic pulmonary aspergillosis in adult asthmatics with ABPA. *Respiratory Medicine*, 109(12), 1509–1515. <https://doi.org/10.1016/j.rmed.2015.09.007>
- Maturu, V. N., & Agarwal, R. (2015). Acute Invasive Pulmonary Aspergillosis Complicating Allergic Bronchopulmonary Aspergillosis: Case Report and Systematic Review. *Mycopathologia*, 180(3–4), 209–215. <https://doi.org/10.1007/s11046-015-9907-0>
- Matzenbacher, C. A., Garcia, A. L. H., dos Santos, M. S., Nicolau, C. C., Premoli, S., Corrêa, D. S., de Souza, C. T., Niekraszewicz, L., Dias, J. F., Delgado, T. V., Kalkreuth, W., Grivicich, I., & da Silva, J. (2017). DNA damage induced by coal dust, fly and bottom ash from coal combustion evaluated using the micronucleus test and comet assay in vitro. *Journal of Hazardous Materials*, 324, 781–788. <https://doi.org/10.1016/j.jhazmat.2016.11.062>
- Miranda-Guevara, A., Muñoz-Acevedo, A., Fiorillo-Moreno, O., Acosta-Hoyos, A., Pacheco-Londoño, L., Quintana-Sosa, M., Moya, Y. D., Dias, J., Souza, G. S. de, Martinez-Lopez, W., Garcia, A. L. H., Silva, J. da, Borges, M. S., Henriques, J. A. P., & León-Mejía, G. (2023). The dangerous link between coal dust exposure and DNA damage: Unraveling the role of some of the chemical agents and oxidative stress. *Environmental Geochemistry and Health*, 45(10), 7081. <https://doi.org/10.1007/s10653-023-01697-3>

- Mousavi, B., Hedayati, M., Hedayati, N., Ilkit, M., & Syedmousavi, S. (2016). Aspergillus species in indoor environments and their possible occupational and public health hazards. *Current Medical Mycology*, 2(1), 36–42. <https://doi.org/10.18869/acadpub.cmm.2.1.36>
- Petrucelli, M. F., Abreu, M. H. de, Cantelli, B. A. M., Segura, G. G., Nishimura, F. G., Bitencourt, T. A., Marins, M., & Fachin, A. L. (2020). Epidemiology and Diagnostic Perspectives of Dermatophytoses. *Journal of Fungi*, 6(4), 310. <https://doi.org/10.3390/jof6040310>
- Rdzanek, M., Pusz, W., Gębarowska, E., & Płaskowska, E. (2015). Airborne bacteria and fungi in a coal mine in Poland. *Journal of Cave and Karst Studies*, 77(3), 177–182. <https://doi.org/10.4311/2015MB0102>
- Ruidas, D., & Pal, S. C. (2022). Potential hotspot modeling and monitoring of PM2.5 concentration for sustainable environmental health in Maharashtra, India. *Sustainable Water Resources Management*, 8(4), 98. <https://doi.org/10.1007/s40899-022-00682-5>
- Sarma, S., Capoor, M. R., Deb, M., Ramesh, V., & Aggarwal, P. (2008). Epidemiologic and clinicomycologic profile of onychomycosis from north India. *International Journal of Dermatology*, 47(6), 584–587. <https://doi.org/10.1111/j.1365-4632.2008.03674.x>
- Shams-Ghahfarokhi, M., Aghaei-Gharehbolagh, S., Aslani, N., & Razzaghi-Abyaneh, M. (2014). Investigation on distribution of airborne fungi in outdoor environment in Tehran, Iran. *Journal of Environmental Health Science and Engineering*, 12, 54. <https://doi.org/10.1186/2052-336X-12-54>
- Sinitsky, M. Yu., Minina, V. I., Gafarov, N. I., Asanov, M. A., Larionov, A. V., Ponasenko, A. V., Volobaev, V. P., & Druzhinin, V. G. (2016). Assessment of DNA damage in underground coal miners using the cytokinesis-block micronucleus assay in peripheral blood lymphocytes. *Mutagenesis*, 31(6), 669–675. <https://doi.org/10.1093/mutage/gew038>
- Sisodia, J., & Bajaj, T. (2024). Allergic Bronchopulmonary Aspergillosis. In *StatPearls*. StatPearls Publishing. <http://www.ncbi.nlm.nih.gov/books/NBK542329/>
- Tulsiyan, R. K., Sinha, N. K., & Kumar, V. (n.d.). Isolation and Identification of Fungi from Coal Mines near Hazaribagh and their Diversity Study. Retrieved July 22, 2024, from <https://www.omicsonline.org/open-access/isolation-and-identification-of-fungi-from-coal-mines-near-hazaribaghand-their-diversity-study.php>
- Veiga, M. M., Maxson, P. A., & Hylander, L. D. (2006). Origin and consumption of mercury in small-scale gold mining. *Journal of Cleaner Production*, 14(3), 436–447. <https://doi.org/10.1016/j.jclepro.2004.08.010>
- Viani, I., Colucci, M. E., Pergreffi, M., Rossi, D., Veronesi, L., Bizzarro, A., Capobianco, E., Affanni, P., Zoni, R., Saccani, E., Albertini, R., & Pasquarella, C. (2020). Passive air sampling: The use of the index of microbial air contamination. *Acta Bio Medica: Atenei Parmensis*, 91(Suppl 3), 92–105. <https://doi.org/10.23750/abm.v91i3-S.9434>
- Wächtler, B., Citiulo, F., Jablonowski, N., Förster, S., Dalle, F., Schaller, M., Wilson, D., & Hube, B. (2012). *Candida albicans*-epithelial interactions: Dissecting the roles of active penetration, induced endocytosis and host factors on the infection process. *PloS One*, 7(5), e36952. <https://doi.org/10.1371/journal.pone.0036952>
- What are the WHO Air quality guidelines? (n.d.). Retrieved October 21, 2024, from <https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines>.