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Prevalence of ophthalmopathology among miners with occupational bronchopulmonary diseases

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Abstract

Dust-related lung diseases, including pneumoconiosis, chronic obstructive pulmonary disease (COPD), and silicosis, continue to be a major cause of disability among miners. The harmful effects of coal and silica dust are not limited to the respiratory system but also negatively impact the visual system. Current scientific data indicate an increase in ophthalmological disorders such as dry eye syndrome, reduced corneal sensitivity, and retinal pathologies. However, this issue remains insufficiently studied.

Ophthalmological diseases in miners with dust-related lung conditions represent a significant but underexplored issue. There is a lack of epidemiological data on the prevalence of ophthalmopathologies among miners in Kazakhstan, highlighting the need to adapt international experience in early diagnosis and prevention of ophthalmological complications.

Key words: miners, occupational diseases, coal dust, ophthalmopathology, dry eye syndrome (DED).

1. Introduction

At present, dust-related lung diseases (DRLDs) are considered one of the main predictors of premature loss of working capacity among young individuals. Dust-induced pulmonary pathologies (pneumoconiosis, chronic obstructive pulmonary disease [COPD], and silicosis) remain a serious global public health issue [1]. According to the Global Burden of Disease (GBD) 2016 study, more than 76 million disability-adjusted life years (DALYs) were attributed to occupational risks [2].

Particular concern arises regarding DRLDs among workers in the coal, metallurgical, and construction industries, where dust concentration is particularly high [3]. Prolonged exposure to coal dust adversely affects not only the respiratory system but also induces systemic dysfunctions in the body, including impairments of the visual apparatus [4]. According to GBD 2019 data, the number of years of life lost due to blindness and visual impairment reached 22.6 million DALYs, with cataract (29.6%), refractive errors (29.1%), near vision impairment (21.7%), vision loss (13.7%), glaucoma (3.3%), and age-related macular degeneration (2.5%) being the leading causes [5]. As a result, both quality of life and work capacity of miners deteriorate significantly [6].

Despite the accelerating global transition to "green" energy, the coal industry remains one of the pillars of the world's energy supply [7]. The hazardous working conditions in coal mines pose potential risks for pathological processes across various organs and systems, including the visual system, contributing to the growing incidence of ophthalmopathologies among miners [8].

There are several primary methods of coal extraction (open-pit, shaft, and mountain mining), depending on the depth of coal seams, geological conditions, and economic feasibility. Workers mining coal at depths greater than 600 meters encounter extremely dust-laden environments, with coal dust concentrations exceeding 3000 mg/m^3, far surpassing permissible thresholds (4 mg/m^3 for total dust according to PC-TWA methodology) [9,10].

Recent studies convincingly demonstrate that under hypoxic conditions excessive production of reactive oxygen and nitrogen species (ROS/RNS) occurs, leading to oxidative stress — the main factor contributing to the development of ophthalmological pathologies in miners. An imbalance between free radicals and protective antioxidant mechanisms results in degradation of cellular membranes and induction of apoptosis in corneal epithelium [11–13].

Inhalation of coal dust at high concentrations causes substantial harm to miners' health, manifesting as headaches, irritation of the throat, nose, and eyes, drowsiness, dyspnea, and nausea [14]. Frequently, coal miners neglect safety protocols and do not use personal protective equipment (PPE) such as protective goggles, helmets, and respirators. Consequently, miners' eyes in underground mines are directly exposed to high dust concentrations [15].

Limited illumination in mining environments further impairs visual functions, manifesting as binocular vision disorders and reduced visuomotor coordination [16]. Moreover, workers in the coal industry often demonstrate impaired tear film function and development of dry eye disease (DED) [17].

Thus, the primary factors increasing the risk of DED among underground coal miners include: prolonged (more than 10 years) work in adverse underground conditions, inhalation of coal dust enriched with crystalline silicon dioxide (SiO_2), and recurrent superficial ocular (corneal and conjunctival) trauma [18].

All of the above-mentioned factors contribute to disability and loss of work capacity among miners, and despite preventive efforts, they continue to affect a significant proportion of the mining workforce each year [19].

Nevertheless, a detailed analysis of contemporary scientific publications demonstrates that ophthalmological aspects of DRLDs remain insufficiently explored, despite existing evidence of the influence of dust-related factors on ocular surface health [20].

Considering the fragmented nature of current knowledge regarding ophthalmological complications among coal industry workers, the objective of this review is to identify and comparatively analyze the nosological spectrum and prevalence of ocular pathologies in individuals with occupational dust-related bronchopulmonary diseases.

2. Materials and Methods

Methodological approach

This review was conducted in accordance with the five-stage methodological framework originally described by Arksey and O'Malley, which includes the following steps: identification of the research question; identification of relevant studies; study selection; charting of data; and collating, summarizing, and reporting results [21]. These core stages were refined using the methodological guidance provided by the Joanna Briggs Institute (JBI), which offers additional clarity regarding protocol development, eligibility criteria, and strategies for data presentation [22].

Scope of studies

The analysis covered publications from 2015 to 2025 without regional restrictions. Primary attention was given to underground coal miners; however, several studies also considered workers in metallurgy and related industries.

Search strategy

The literature search was conducted in electronic databases including PubMed, Scopus, and Web of Science. Additionally, relevant materials not indexed in leading scientific databases but containing valuable information were included.

Data extraction

Data were systematized in a standardized extraction form created in Microsoft Excel. The form included fields for study characteristics such as country and sample size, nosological classification, prevalence, as well as keywords and key findings.

Inclusion criteria

Publications from 2015–2025:

1. studies addressing ophthalmopathologies in miners and patients with dust-related bronchopulmonary diseases;
2. exposure: coal and/or silica dust;
3. types of publications: systematic and descriptive reviews, clinical and observational studies;
4. outcomes: ophthalmological nosologies with reported prevalence or frequency.

Exclusion criteria

1. lack of relevance to occupational dust exposure (e.g., general ophthalmological or respiratory diseases unrelated to industrial dust);
2. Absence of empirical data;
3. Publications outside the 2015–2025 timeframe;
4. Articles without an English-language or accessible full-text version.

3. Results and discussion

The review of findings was presented in a descriptive format. Due to heterogeneity of study designs, outcomes, and diagnostic methods, meta-analysis was not performed. Instead, data were grouped into thematic clusters covering: nosological forms of ophthalmopathologies among miners, prevalence in different countries, risk factors and pathogenesis, diagnostic methods, and socio-economic implications.

Study selection

The study selection process involved a comprehensive search of major databases (PubMed, Scopus, Web of Science) and assessment of additional

relevant materials. Initially, 108 records were identified. After duplicate removal and screening of titles and abstracts, 54 articles were selected, of which 47 were excluded as irrelevant. The final synthesis included 7 full-text studies: 5 original clinical investigations, 1 cohort study, and 1 descriptive study. Research conducted across different countries consistently confirmed the identified trends.

Comparative analysis

The analysis demonstrated a widespread occurrence of ophthalmological disorders among miners. Literature sources indicated that dry eye disease (DED) is the most common condition among miners, reported in five out of six countries. Other ophthalmological disorders exhibited regional specificity: corneal microtrauma was characteristic of Ukraine, conjunctivitis and blepharitis of Russia, pterygium and keratitis of Pakistan, binocular vision disorders of India, and retinal changes of China.

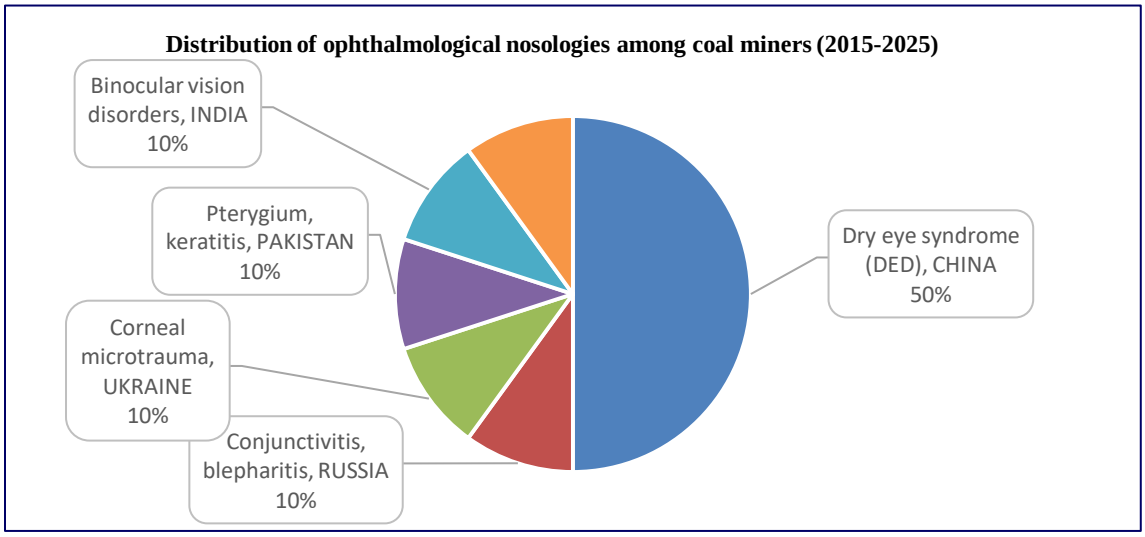

Figure 1 - Nosology and prevalence of ocular diseases among miners in different countries (2015–2025)

According to a study conducted by the Chinese Institute of Ophthalmology in 2023, the prevalence of dry eye disease (DED) among miners was 35–45%, which significantly exceeded the rates observed in the control group (OR = 1.26; 95% CI: 1.14–1.30; $p < 0.001$) [23]. Moreover, Chinese miners demonstrated thinning of the retinal nerve fiber layer (RNFL) and vascular alterations, which were statistically different from the control population [24].

A study conducted in the Kuznetsk Coal Basin (Kuzbass) in the Russia, one of the largest coal deposits in the world, revealed a high prevalence of conjunctivitis, blepharitis, and DED in 30–40% of cases among miners with more than 10 years of work experience [25].

According to research by Bulent Ecevit University in Turkey, miners with dust-related lung diseases, particularly pneumoconiosis, demonstrated DED and tear film instability in 50% of cases [26].

A study conducted in 2024 by Liaquat University of Medical and Health Sciences in collaboration with the People's Nursing School of Pakistan identified a high frequency of pterygium, keratitis, and DED (50–60%) among miners with more than 6 years of work experience. The authors emphasized the unfavorable working conditions, including extended shifts, lack of adequate eye protection, and insufficient medical monitoring [27].

Publications from the Department of Ophthalmology, Bangalore Medical College, India [28], mainly focused on functional vision disorders such as binocular vision and visuomotor coordination. The authors associated these changes not only with dust

exposure but also with insufficient lighting in mines, highlighting the role of additional occupational factors.

Ukrainian data published by Ivano-Frankivsk Medical University [29] indicated a high prevalence of dry eye disease (40%) and corneal microtrauma (20–25%) among miners working in dusty conditions for more than 10 years.

The findings presented in Table 1 clearly demonstrate that dry eye disease (DED) is the predominant ophthalmological pathology among miners in most of the studied countries.

Table 1 - Distribution of ophthalmological nosologies among miners according to the literature (2015–2025). Dry eye disease (DED) was the most frequently reported disorder, documented in five out of six countries

Country, year	Type of mines	n - miners	Nosology	Method	Frequency
China (Huainan), 2023	Underground coal	3749	Dry eye syndrome (DED)	OSDI questionnaire	35-45%
China (Kailuan), 2022	Underground coal	4004	RNFL thinning and vascular changes, OCT and vascular analysis	OCT, vascular analysis	Statistically significant compared with controls
Russia (Kuzbass), 2019	Underground coal	2217	Conjunctivitis, blepharitis, DED	Descriptive statistics	30–40% among workers with >10 years of experience
Turkey, 2017	Underground coal	46	DED, tear film instability (>50%)	Schirmer test, BUT.	>50 %
India, 2024	Underground coal	64	Binocular vision disorders (20–30%)	Prospective cross-sectional study	20-30%
Pakistan, 2021	Underground coal	317	Pterygium, DED, keratitis	Descriptive cross-sectional study, diagnostic standards for NSBVD	50–60% with >6 years of experience
Ukraine, 2018	Underground coal	250	DED (40%), corneal microtrauma	clinical examination, Schirmer test, BUT	DED - 40%, microtrauma 20-25%

The analysis highlighted regional features of ophthalmological disorders affecting both the anterior (conjunctiva, cornea) and posterior (retina) segments of the eye. These findings confirm that chronic exposure to coal and silica dust contributes to a wide spectrum of ophthalmological complications, while scientific interest in different countries has been directed toward specific clinical manifestations.

4. Discussion

Several factors contribute to the etiopathogenesis of ophthalmological diseases, with oxidative stress (OS) playing a central role in various forms of retinopathy. In particular, Nebbioso et al. [30] considered OS a key pathogenic mechanism in DED, which is supported by the studies of Pflugfelder, de Paiva (2017), and Dammak et al. [31,32]. Similarly, Malaviya and colleagues [33] identified associations between chronic NADPH oxidase activation, mitochondrial dysfunction, and lipid peroxidation in the retina. The findings of Chen et al. [34], demonstrating the protective effect of fullerenol in reducing corneal damage under UV exposure, further confirm the role of reactive oxygen species (ROS) as critical damaging agents.

Chronic hypoxia, a characteristic feature of the pathogenesis of pneumoconiosis and COPD in miners, also represents a significant factor in the development of ophthalmological complications. Hypoxic conditions lead to impaired microcirculation and ischemic changes in ocular tissues. Research conducted in China and Russia has demonstrated statistically significant differences in RNFL thickness and vascular status among miners with dust-related lung diseases compared with control groups, confirming the role of chronic hypoxia in the development of retinopathies.

A third important mechanism is systemic inflammation triggered by ROS. It has been shown that OS activates pro-inflammatory cytokines (IL-6, TNF-α), which intensify inflammatory changes in the tear film and contribute to retinal damage. The study of inflammatory biomarkers is of primary importance. According to Ozcan D. Ozarslan et al. [35], elevated levels of IL-6 and IL-10 were recorded in patients with DED, indicating the involvement of systemic inflammatory responses in the pathogenesis of the disease. Comparable findings were presented by H.H. Wang and colleagues [36], who identified IL-6 as a key indicator of tear film dysfunction. Review articles by K. Narendra and D. Huang [37] further emphasized the universality of these cytokines in assessing the degree of inflammatory processes in ophthalmopathologies associated with aerosol particle exposure.

Similar mechanisms were described by Valle et al. [38] in studies of diabetic retinopathy, highlighting the universality of inflammatory processes in ocular pathologies and allowing extrapolation to the miner population exposed to chronic dust exposure. These conclusions are consistent with the work of Kowluru and Malaviya [39], who demonstrated that mitochondrial dysfunction and depletion of antioxidant systems are major drivers of chronic ocular inflammation.

Currently, MMP-7 and SP-D are recognized biomarkers of fibrosis and inflammation. These markers, known for their roles in interstitial lung diseases and tissue remodeling processes, allow assessment of the degree of damage and prediction of disease progression. Studies have shown that MMP-7 is an independent predictor of progression and mortality in pulmonary fibrosis, while the combination of SP-D and MMP-7 aids in the differential diagnosis of idiopathic pulmonary fibrosis [40,41]. In the ophthalmological context, these mechanisms are of particular importance, since chronic inflammation and fibrosis can lead to tear film and ocular surface damage. Moreover, SP-D exerts a protective effect on the ocular surface, reducing infection risk and supporting epithelial stability in DED [42]. Therefore, elevated levels of these biomarkers may contribute to the development of ocular complications in miners.

Taken together, the available evidence confirms that three synergistic pathogenetic processes — oxidative stress, hypoxia, and systemic inflammation — form the etiological basis of ophthalmological pathologies among coal industry workers. Clinically, these manifest as dry eye disease, corneal damage, corneal hypoesthesia, as

well as vascular and neurodegenerative changes in the retina (Figure 2).

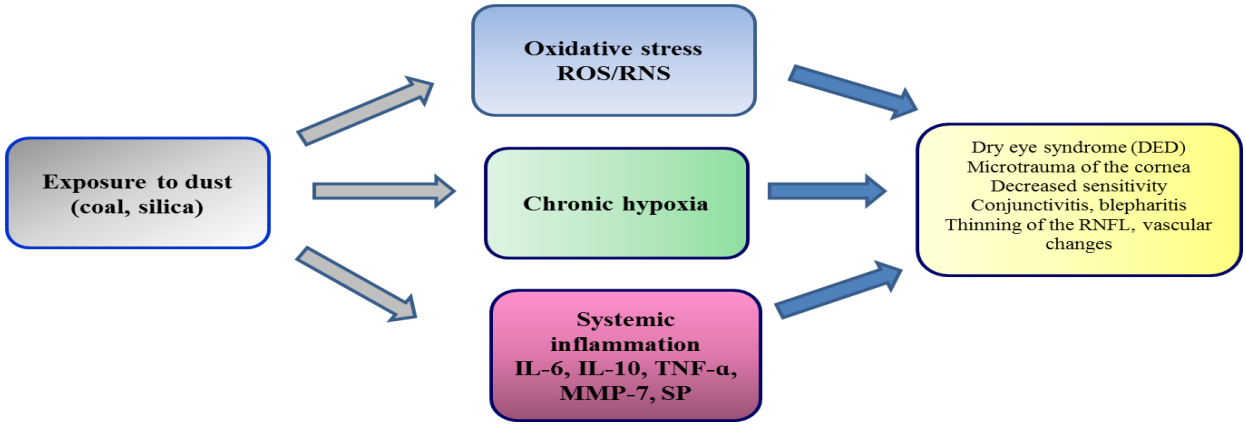

Figure 2 - Pathogenesis of ocular complications in miners. Exposure to coal and silica dust induces oxidative stress, hypoxia, and systemic inflammation. These processes lead to damage of the anterior segment of the eye (dryness, corneal microtrauma, conjunctivitis) and the posterior segment (RNFL thinning, vascular changes)

The prevalence of ophthalmological diseases among miners carries profound social and economic implications. Visual impairment directly reduces miners' work capacity, increases occupational injury risk, and often necessitates early termination of employment. This, in turn, imposes additional burdens on healthcare and social security systems, as well as on compensation programs provided by employers. According to Petsonk et al. [43], dust-related lung diseases exert significant socio-economic impacts, including increased healthcare costs and reduced labor productivity among miners.

For coal-producing regions, where the coal industry plays a pivotal role in the economy and where large populations of workers are exposed to dust, vision loss or deterioration among miners has especially severe social and economic consequences. Therefore, ophthalmopathologies in miners should be regarded not only as a medical issue but also as a factor generating substantial additional social and economic burdens for industrial regions.

5. Conclusions

The analysis of collected scientific evidence demonstrated that, despite the general trend of high prevalence of ocular pathologies among coal industry workers, the research focus varies considerably across countries. These differences are determined both by methodological approaches and by specific working conditions in different regions.

In the context of Kazakhstan, where dust-related lung diseases are widespread among coal industry workers, there is a notable lack of data on the prevalence of ophthalmological complications in available sources. It is assumed that even if relevant studies were conducted, their findings were either not published in international databases or remain inaccessible for analysis. This situation creates a critical gap in understanding the impact of occupational dust factors on the visual system and highlights the need for national-level research.

Despite the variety of reported conditions, all studies confirm that the eyes of miners represent a key target organ affected by occupational risk factors. The

variability in findings across countries is more likely related to differences in research emphasis and workplace conditions rather than to the specific characteristics of the pathologies themselves.

This review systematized domestic and international evidence regarding the types and prevalence of ophthalmological diseases among miners exposed to coal and silica dust:

– Dry eye disease (DED) is the most frequently reported ocular manifestation in miners exposed to long-term coal dust, with prevalence ranging from 30–45% in published studies from China, Ukraine, Russia, and Turkey. This allows it to be considered a key indicator of occupational dust-related ocular impact.

– In addition to DED, miners are affected by various ocular pathologies, including inflammatory disorders of the conjunctiva and eyelids (conjunctivitis, blepharitis), corneal damage (microtrauma, pterygium, keratitis), binocular vision disorders, as well as retinal changes (RNFL thinning, vascular abnormalities). These findings reflect the complex and multifactorial impact of dust exposure on both the anterior and posterior segments of the eye.

– The results of this review emphasize the importance of incorporating ophthalmological complications into the broader context of occupational diseases. They can serve as a foundation for developing rehabilitation programs aimed at the prevention and protection of miners' vision.

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Бронхөөкпе жүйесінің кәсіптік аурулары бар кеншілерде офтальмопатологияның таралуы

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Түйіндеме

Өкпенің шаңды аурулары, соның ішінде пневмокониоз, өкпенің созылмалы обструктивті ауруы (ӨСОА) және силикоз, шахтерлер арасында еңбекке жарамдылықты жоғалтудың негізгі себептерінің бірі болып қалуда. Сонымен қатар, көмір мен кремний шаңының зиянды әсері тек тыныс алу жүйесімен шектелмей, көру ағзаларына да кері әсерін тигізеді. Қазіргі ғылыми деректер көз ауруларының, мысалы, құрғақ көз синдромы,

қасаң қабықтың сезімталдығының төмендеуі және тор қабық патологияларының жиілеуін көрсетеді, алайда бұл мәселе әлі де жеткіліксіз зерттелген.

Шаңды өкпе аурулары бар шахтерлердегі офтальмологиялық аурулар — маңызды, бірақ жеткіліксіз зерттелген мәселе. Қазақстанда шахтерлер арасында офтальмопатологиялардың таралуы туралы эпидемиологиялық деректер жоқ, бұл көз ауруларының ерте диагностикасы мен алдын алуда халықаралық тәжірибені бейімдеудің қажеттілігін көрсетеді.

Түйін сөздер: шахтерлер, кәсіби аурулар, көмір шаңы, офтальмопатология, құрғақ көз синдромы (DED).

Распространённость офтальмопатологии у шахтеров с профессиональными заболеваниями бронхопульмональной системы

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Резюме

Пылевые заболевания легких, включая пневмокониоз, хроническая обструктивная болезнь легких и силикоз, продолжают оставаться основной причиной потери трудоспособности среди шахтеров. При этом вредное воздействие угольной и кремниевой пыли не ограничивается дыхательной системой, оказывая негативное влияние и на органы зрения. Современные научные данные свидетельствуют о росте офтальмологических нарушений, таких как синдром сухого глаза, снижение чувствительности роговицы и патологии сетчатки, однако эта проблема изучена недостаточно.

Офтальмологические заболевания у шахтёров с пылевыми заболеваниями лёгких представляют собой значимую, но недостаточно исследованную проблему. В Казахстане отсутствуют эпидемиологические данные о распространённости офтальмопатологий у шахтёров, что подчёркивает необходимость адаптации международного опыта ранней диагностики и профилактики офтальмологических осложнений.

Ключевые слова: шахтёры, профессиональные заболевания, угольная пыль, офтальмопатология, синдром сухого глаза (DED).