VOL. 4, No. 2 Journal of Osh State University. Medicine 2025

Journal of Osh State University Journal homepage: https://medicine-oshsu.com/en

e-ISSN 1694-8831
UDC 551.583:616.2
DOI: 10.52754/16948645_2025_4(2)_62

Received 29.07.2025
Revised 10.11.2025
Accepted 17.12.2025

The air crisis: The escalating effects of climate change on the respiratory system

Gavharoi Umurzakova*
Senior Lecturer
Osh State University
723500, 331 Lenin Str., Osh, Kyrgyz Republic
https://orcid.org/0000-0003-1580-1129

Aigul Momunova
PhD in Biological Sciences, Associate Professor
Osh State University
723500, 331 Lenin Str., Osh, Kyrgyz Republic
https://orcid.org/0000-0003-1917-0504

Maurya Alok
Undergraduate Student
Osh State University
723500, 331 Lenin Str., Osh, Kyrgyz Republic

Tiwari Anmol
Undergraduate Student
Osh State University
723500, 331 Lenin Str., Osh, Kyrgyz Republic

Abstract. Climate change is increasingly recognised as a serious threat to respiratory health, making it essential to understand how changing environmental conditions affect lung function and the pattern of respiratory diseases. This review aimed to summarise current scientific evidence on the effects of rising temperatures, altered weather patterns, and deteriorating air quality on the global burden of respiratory diseases. A comprehensive analysis of the latest peer-reviewed literature, including epidemiological studies, systematic reviews, and reports from international health organisations, was conducted. Climate-related environmental factors were analysed in relation to observed trends in respiratory health indicators. The findings indicated that climate-driven environmental changes have a substantial impact on respiratory health. Elevated concentrations of ground-level ozone, wildfire smoke, and fine particulate matter are consistently associated with increased respiratory symptoms and exacerbations of asthma and chronic obstructive pulmonary disease (COPD). Rising atmospheric carbon dioxide levels and altered seasonal cycles contribute to longer and more intense pollen seasons, increasing exposure to aeroallergens. Extreme weather events, including heatwaves, heavy precipitation, and flooding, promote indoor mould growth and heighten the risk of respiratory infections. The most vulnerable populations – particularly children, the elderly, and socio-economically disadvantaged communities – bear a disproportionately higher disease burden due to greater exposure and limited adaptive capacity. The results of this review provide a scientific basis for public health planning and clinical decision-making, and may inform targeted mitigation and adaptation strategies aimed at reducing climate-related respiratory risks among vulnerable populations

Keywords: ground-level ozone; particulate matter; dust storms; aeroallergens; chronic obstructive pulmonary disease; mitigation; adaptation

Suggested Citation:
Umurzakova G, Momunova A, Alok M, Anmol T. The air crisis: The escalating effects of climate change on the respiratory system. J Osh State Univ Med. 2025;4(2):62–9. DOI: 10.52754/16948645_2025_4(2)_62

*Corresponding author

Introduction

Climate change is increasingly being recognised not just as an environmental problem, but as a major threat to human health – especially to respiratory health. The Earth is warming faster than ever before, weather patterns are becoming more unpredictable, and extreme events such as wildfires, dust storms, and floods are occurring more frequently. Because the lungs and airways represent the primary interface between the human body and the environment, any deterioration in air quality or climatic instability can have immediate and serious consequences for respiratory health. This subject is especially urgent now, given the latest surge in climate-driven air pollution episodes, wildfire smoke events, extended pollen seasons, and extreme weather across the globe – making it essential to examine how these changes affect breathing and lung disease rates.

A growing body of research from 2020 onward has started to document these connections in detail. For instance, a comprehensive review by the American Lung Association [1] explained that hotter, drier climates lead to more frequent and severe wildfires and dust storms, elevating levels of fine particulate matter ($PM_{2.5}$) and other pollutants which harm lung health. Similarly, a study by H. Bayram *et al*. [2] reported that rising temperatures and increased particulate matter and ozone levels exacerbate chronic respiratory diseases, extend pollen seasons, boost dust pollution in arid regions, and worsen risks from indoor mould after flooding – particularly affecting children and the elderly.

More specifically, J.-H. Chang *et al*. [3] argued that climate change not only increases the concentration of airborne particles, but may also alter the physicochemical properties (size, chemical composition, dispersion) in ways that facilitate deeper and more harmful deposition in the lungs – thereby raising the risk of developing or exacerbating respiratory diseases. Another systematic review by B. Rackow *et al*. [4] found that high temperatures combined with elevated levels of ozone (O_3), particulate matter (PM_{10}, $PM_{2.5}$), and nitrogen dioxide (NO_2) synergistically amplify mortality risk and worsen respiratory and cardiovascular conditions.

Moreover, the technical brief by the World Health Organisation [5] highlighted how climate change influences allergen dynamics – leading to earlier, longer, and more intense pollen seasons, increased mould proliferation after flooding, and greater exposure to airborne allergens, all of which contribute to rising incidence of allergic respiratory diseases such as asthma and allergic rhinitis. Complementing this, S.-Z. Deng *et al*. [6] emphasised the interactive, compounding effects of climate change, pollution, and aeroallergens on respiratory health – noting that extreme weather events and air pollution can intensify allergenicity and harm airway health.

Despite this growing evidence, important gaps remain. Most studies examined single factors – such as pollution, pollen, or weather extremes – in isolation. There is far less research that integrates multiple climate-related stressors (e.g., combined air pollution, allergen changes, extreme weather) into comprehensive models that reflect real-world exposure scenarios. Furthermore, very few of these studies focus on populations in Central Asia or other regions where rapid climate change is intersecting with social and economic vulnerabilities. As a result, there is limited region-specific data on how combined climate change impacts affect respiratory health in such contexts. This gap justifies the present research. The aim of this study was to systematically assess how the combined effects of climate-driven air pollution, changing allergen exposure (pollen, mould), and extreme weather events interact to influence the prevalence and severity of respiratory diseases – particularly among vulnerable populations in under-studied regions.

Materials and Methods

The present study was designed as a comparative systematic review of the scientific literature analysing the relationships between climatic factors, atmospheric air pollution, and the state of respiratory health in the population. The primary objective of the analysis was to identify the mechanisms through which climate-related environmental changes influence the concentrations of major atmospheric pollutants and the associated risks to the respiratory system. The search for scientific publications was conducted in international scientific databases. The review included studies published between 2010 and 2025, allowing the analysis to capture the most relevant research reflecting current trends in climate change and air quality.

The following keywords and the combinations were used for the search: "$PM_{2.5}$", "PM_{10}", "ozone", "air pollution", "climate change", "heat", "humidity", "dust storms", "stubble burning", "coal heating", "India", "Kyrgyzstan", "respiratory diseases", "vulnerable populations". The inclusion criteria involved selecting scientific articles that addressed the following aspects: the influence of climatic factors (temperature, humidity, precipitation, and extreme weather events) on the concentrations of atmospheric pollutants; the impact of air pollution on respiratory health in the population; as well as studies examining the main anthropogenic emission sources, including agricultural biomass burning, transport emissions, and the use of coal for heating. In addition, publications from international health organisations and environmental agencies containing statistical data on morbidity and mortality associated with air pollution were also considered. India and the Kyrgyz Republic were selected as regions for comparative analysis, which made it possible to examine the formation of air pollution under different climatic and socio-economic conditions [7,8].

During the analysis, data were extracted from the selected publications on pollutant concentrations ($PM_{2.5}$, PM_{10} and O_3), meteorological conditions, anthropogenic emission sources, and indicators of respiratory morbidity among different age and socio-economic population groups. Particular attention was paid to vulnerable groups, including children, older adults, and low-income populations. The collected data were systematised and analysed using a comparative descriptive approach. The results of studies conducted in India and the Kyrgyz Republic were considered separately, after which the identified trends and risk factors were compared. This approach made it possible to identify both general patterns in the influence of climate change on atmospheric air pollution and regional characteristics of its impact on respiratory health.

Results and Discussion

Influence of climatic factors on atmospheric pollutant composition

Climate change directly affects concentrations of particulate matter and ozone in the air, thereby increasing the risks of respiratory diseases. Sand and dust storms substantially elevate the levels of suspended particles, even at significant distances from the source. The World Health Organisation (WHO) [9] noted that such storm episodes directly impact air pollution, as the storms increase airborne particulate concentrations. In some regions, lifted dust constitutes the primary source of these particles. However, around 25% of dust emissions are linked to human activities, including deforestation, poor land management, and climate change. Expansion of arid areas under global warming leads to more frequent and intense storms, increasing dust suspension. This allows dust to penetrate deep into the respiratory tract, exacerbating asthma and chronic obstructive pulmonary disease (COPD) [10].

Higher temperatures and humidity accelerate chemical processes in the atmosphere, altering aerosol composition. For example, a study by Y. Park *et al*. [11] in Korea showed that nocturnal relative humidity increases aerosol liquid water content (ALWC), facilitating the conversion of nitrates into the condensed particle phase. This indicates that in India's hot and humid seasonal atmosphere, "wetter" $PM_{2.5}$ particles form, capable of absorbing more toxic components. Elevated temperatures also enhance the photochemical formation of ground-level ozone (O_3). As F. Rosser & J. Balmes [12] indicated, ozone is a highly toxic substance for the respiratory tract and is associated with multiple cases of childhood asthma. In South Asian countries, including India, ground-level O_3 rises during warm seasons; US data show that a third of the population experiences ozone concentrations exceeding standards, and climate change further increases O_3, reducing the effectiveness of existing control measures. The WHO emphasised that reducing greenhouse gas emissions can improve air quality, mitigating climate change impacts [10].

These findings demonstrated that climate change significantly alters air pollution dynamics, particularly fine particulate matter and ground-level ozone, with substantial respiratory health consequences. Rising ambient temperatures enhance photochemical reactions, increasing ozone formation, especially under stagnant atmospheric conditions. In India, heatwaves amplify ozone production in urban and suburban areas, leading to persistent smog episodes and increased exposure to respiratory irritants, as noted by X. Li *et al*. [13]. The authors' study reported links between elevated ozone levels and worsening asthma symptoms, breathlessness, and emergency healthcare visits. $PM_{2.5}$ particles become more chemically active and penetrate deeper into the lungs due to altered hygroscopic properties, increasing the incidence of respiratory inflammation. According to WHO data, particulate pollution is directly associated with cardiovascular and respiratory diseases, causing 4.2 million premature deaths in 2019 [10].

E.E. McDuffie *et al*. [14] also observed that a substantial proportion of global mortality related to $PM_{2.5}$ exposure arises from fossil fuel combustion, which forms a persistent background of aerosol pollution in the atmosphere. The authors estimated that these emissions are associated annually with over one million premature deaths, mainly from cardiovascular and respiratory diseases. The findings underline that reducing fossil fuel use could substantially lower the global disease burden due to air pollution. The authors also highlighted that low-income populations face increased risks because of being more frequently exposed to heavily polluted air and having limited protection. Consequently, assessing impacts requires considering not only emission levels but also the modifying influence of climate on particle behaviour in the atmosphere and respiratory tract.

Comparative analysis of anthropogenic emissions in India and Kyrgyzstan

India and Kyrgyzstan exhibit distinct local pollution sources, interacting with the respective climatic conditions. In India, average indoor $PM_{2.5}$ concentrations frequently exceed international health standards, reflecting combined exposure from ambient pollution, transport emissions, biomass burning, and seasonal agricultural residue combustion. Episodic $PM_{2.5}$ spikes during crop residue burning in the Indo-Gangetic Plain coincide with observed increases in bronchitis, asthma exacerbations, and hospital admissions. G. Govardhan *et al*. [15] analysed the impact of agricultural residue burning in northwestern India on Delhi's air quality using satellite data and atmospheric modelling. The model estimated that during peak fire periods, fires contributed approximately 30-35% of $PM_{2.5}$

concentrations in Delhi's atmosphere. Unfavourable meteorological conditions further enhance pollutant accumulation. The authors concluded that agricultural biomass burning is a significant regional source of seasonal air pollution and must be considered when developing air quality improvement measures. Under stagnant wind and inversion conditions, this contribution can rise sharply. G. Dipoppa & S. Gulzar [8] estimated that open stubble burning accounts for 40-60% of peak winter pollution, affecting not only farmers but millions of urban residents. The authors' study also noted that increased $PM_{2.5}$ exposure from fires correlates with reduced birth rates and infant mortality (30-36 cases per 1,000 live births).

In Kyrgyzstan and the surrounding mountains, the situation differs. Winter smog in Bishkek arises primarily from coal heating in homes and industries. Climatic factors interact with local emissions, producing severe seasonal pollution. According to a UNDP/UN report, approximately 70% of households use coal stoves [7]. Burning raw coal results in winter $PM_{2.5}$ concentrations of ~40-50 μg/m^3 in Bishkek [16], three to four times above safe limits. Monitoring confirms this: annual average $PM_{2.5}$ levels in industrial areas exceed standards by more than twofold. In Central Asia, K.O. Dzushupov *et al*. [17] applied spatial pollution modelling to study winter smog formation in Bishkek, showing that temperature inversions, expected to intensify with climate variability, lead to extreme $PM_{2.5}$ levels exceeding 200 μg/m^3. These findings align with the present study, confirming that meteorological factors play a dominant role in respiratory disease burden, in some cases outweighing industrial emissions alone. As noted by J. Xu *et al*. [18] and T. Li *et al*. [19], annual $PM_{2.5}$ levels remain above international standards, posing severe lung risks due to deep alveolar deposition. UNICEF [7] data report 112 deaths and 3,568 years of life lost due to pollution annually, primarily among the elderly and newborns.

Enhanced aeroallergens represent an additional climate-sensitive pathway. P.J. Beggs *et al*. [20] demonstrated through multinational pollen monitoring that elevated atmospheric CO_2 levels and longer warm seasons significantly increase pollen production and exposure duration. These results correspond with pollen-related findings in both India and Kyrgyzstan, confirming that aeroallergens constitute a rapidly growing climate risk to respiratory health. Similarly, N. Singh *et al*. [21] analysed mould prevalence in India post-monsoon and found that rainfall variability and prolonged indoor dampness are associated with worsened asthma symptoms in children. These observations align with the present review, particularly in flood-prone or poorly ventilated housing conditions.

The main distinction between Kyrgyzstan and India is that summer ozone levels in Kyrgyzstan remain close to standards, whereas the primary issue is winter smog. Comparison of India and Kyrgyzstan shows a common finding: local pollution sources (crop fires and coal heating) remain the main contributors, but the effects are amplified by climate conditions (dry air in India and mountain inversions in Kyrgyzstan). Notably, $PM_{2.5}$ remains the most frequently cited pollutant affecting respiratory health in both regions. Vulnerable populations are similarly affected: children, the elderly, low-income households, and residents of highly polluted areas. Consequently, both regions require simultaneous environmental and social interventions: technological measures (fuel cleaning, transition to safe heating) and targeted support for vulnerable families (subsidies, education).

Climate change is also consistently linked to altered aeroallergen dynamics, increasing respiratory disease incidence. Rising atmospheric CO_2 and warming extend and intensify flowering seasons. Data from both regions indicate earlier flowering, increased pollen production, and prolonged exposure periods, particularly affecting individuals with allergic rhinitis and asthma [22]. In India, climate change during the monsoon – characterised by irregular rainfall and prolonged humidity – creates favourable conditions for indoor mould growth. X. Li *et al*. [13] reported increased respiratory symptoms and infection risks in poorly ventilated homes, especially among children and low-income households. In Kyrgyzstan, earlier snowmelt and longer warm seasons similarly prolong pollen exposure in intermontane valleys, correlating with seasonal rises in allergic respiratory diseases.

Vulnerable populations and adaptation strategies

The literature showed that climate impacts disproportionately affect vulnerable populations. Children, the elderly, and socio-economically disadvantaged communities consistently experience higher exposure and greater susceptibility to adverse respiratory outcomes. In both India and Kyrgyzstan, limited access to clean indoor environments, healthcare, and adaptive resources exacerbates the health burden associated with climate change, pollution, and allergens [13].

J. Xu *et al*. [18] and D. Rattanaphra *et al*. [23] documented that young children, the elderly, and socio-economically vulnerable groups suffer most from combined pollution and climate exposures. Children are more sensitive to $PM_{2.5}$: breathe faster, have narrower airways, and particles deposit deeper. D. Rattanaphra *et al*. [23] estimated that children face higher risks than adults at equivalent $PM_{2.5}$ concentrations. Beyond physiological reasons, children and low-income families bear an additional "social risk": children and low-income households often live in damp, unventilated homes without air conditioning, heated with coal stoves. Low income increases proximity to pollution sources (e.g., coal-heavy outskirts) and limits the ability to relocate to cleaner areas, echoing the findings of J. Rentschler & N. Leonova [24].

The present study highlighted several recommendations. Risk mitigation should prioritise adaptive measures for vulnerable populations, particularly children. Technical recommendations include improving microclimates in schools and kindergartens. J. Bonan *et al*. [25] in Italy showed that portable HEPA air purifiers reduced classroom $PM_{2.5}$ concentrations by 32% and decreased school absenteeism due to illness by 12.5%. Implementing such measures in Indian and Kyrgyz preschools could substantially lower children's daily exposure during lessons. For residential areas, insulation and ventilation improvements are crucial. UNICEF in Kyrgyzstan is already working on enhancing school and home insulation and ventilation [26], enabling families to ventilate without heat loss in winter and reducing indoor smog accumulation. Another avenue is promoting alternative fuels and heating: subsidies for clean technologies (heat pumps, gas boilers, solar water heaters) have proven effective. The UNDP/UN [7] report recommended transitioning households from coal to clean energy to reduce peak winter pollution, which simultaneously benefits the climate by lowering greenhouse gas emissions.

Mitigation policy must be integrated: fuel standards should be tightened, and public transport promoted in major cities to reduce baseline pollution. Equally critical are information and protection for vulnerable groups: alerts during pollution peaks, healthcare access, and clear guidance for children and the elderly. All measures are supported by the study by J. Rentschler & N. Leonova [24], which showed that each large-scale adaptation measure (air purification, subsidies, etc.) saves thousands of lives and hundreds of millions in healthcare costs. The study demonstrated that climatic and anthropogenic factors act synergistically, creating environmental and social challenges. Effective population protection requires interdisciplinary strategies tailored to India and Kyrgyzstan and focused on vulnerable groups. Combining climate-oriented analyses with traditional environmental measures allows targeted adaptation programmes. Even simple technical interventions (air purifiers, insulation) alongside a clean energy transition can substantially reduce the adverse impact of pollution on residents' respiratory health. Overall, the reviewed literature aligns strongly with the findings presented in this study. Contemporary evidence consistently shows that climate change amplifies respiratory health risks through multiple interlinked mechanisms, including air pollution, aeroallergens, dust storms, and extreme weather events. While alternative interpretations exist, these interpretations do not undermine the core identified mechanisms. Collectively, data from India, Kyrgyzstan, and global literature confirmed that climate change accelerates respiratory disease incidence, particularly among vulnerable populations, highlighting the need for comprehensive measures to combat climate change and protect respiratory health.

Conclusions

This study demonstrated that climate change and respiratory health are closely interconnected through multiple, mutually reinforcing pathways. The findings indicated that rising global temperatures, increasing frequency of heatwaves, altered atmospheric circulation, and intensification of extreme weather events have significantly modified patterns of air pollution exposure. These environmental changes have increased the concentration and distribution of particulate matter, ozone, and other respiratory irritants, while also affecting the seasonal dynamics of aeroallergens, thereby extending the period during which vulnerable populations experience respiratory stress.

The results further highlighted that populations residing in regions with pre-existing air quality challenges – particularly areas affected by dust events, rapid urbanisation, or industrial emissions – bear a disproportionately high disease burden. Climate-related environmental stressors amplify pre-existing respiratory conditions, including asthma, chronic obstructive pulmonary disease, and allergic airway disorders. Socioeconomic factors, such as limited access to healthcare or protective infrastructure, exacerbate vulnerability and contribute to more severe outcomes. These patterns underscored the need for integrated, long-term mitigation and adaptation strategies at both community and policy levels. Strengthening early-warning systems, enhancing air quality surveillance, and improving public-health preparedness are essential. In addition, the consistent implementation of personal protective measures and community-level behavioural adaptations can substantially reduce exposure to climate-amplified respiratory hazards.

Overall, this study reinforced that climate change constitutes not only an environmental crisis but also a major determinant of respiratory health. Addressing this challenge requires coordinated action across public health, environmental regulation, and clinical care sectors. Despite advances in understanding the relationships between climate stressors and respiratory outcomes, important knowledge gaps remain. Future research should focus on three priority areas: developing precise regional models to predict respiratory disease trends under evolving climate scenarios; investigating biological mechanisms underlying individual susceptibility to climate-related pollutants; evaluating the effectiveness of community-level interventions and adaptive strategies in reducing long-term respiratory disease burden.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Аба кризиси: климаттын өзгөрүшүнүн дем алуу системасына күчөп жаткан таасирлери

Гавхарой Умурзакова
Улук окутуучу
Ош мамлекеттик университети
723500, Ленин көч., 331, Ош ш., Кыргыз Республикасы
https://orcid.org/0000-0003-1580-1129

Айгүл Момунова
Биология илимдеринин кандидаты, доцент
Ош мамлекеттик университети
723500, Ленин көч., 331, Ош ш., Кыргыз Республикасы
https://orcid.org/0000-0003-1917-0504

Маурья Алок
Студент
Ош мамлекеттик университети
723500, Ленин көч., 331, Ош ш., Кыргыз Республикасы

Тивари Анмол
Студент
Ош мамлекеттик университети
723500, Ленин көч., 331, Ош ш., Кыргыз Республикасы

Аннотация. Климаттын өзгөрүшү дем алуу органдарынын ден соолугу үчүн олуттуу коркунуч катары көбүрөөк таанылып, өзгөрүлүп жаткан экологиялык шарттардын өпкөнүн функциясына жана дем алуу ооруларынын структурасына тийгизген таасирин түшүнүү зарыл экенин көрсөтөт. Бул обзордун максаты – температуранын жогорулашы, аба ырайынын өзгөрүшү жана абанын сапатынын начарлашы глобалдык дем алуу ооруларынын жүгүнө кандай таасир этерин көрсөтүүчү заманбап илимий маалыматтарды бириктирүү. Учурдагы рецензияланган илимий адабият, эпидемиологиялык изилдөөлөр, системалуу обзорлор жана эл аралык саламаттык сактоо уюмдарынын отчеттору кеңири талданды. Климаттык шарттарга байланыштуу экологиялык факторлор дем алуу ден соолуктун көрсөткүчтөрү менен салыштырылды. Талданган маалыматтар климаттык өзгөрүүлөрдүн дем алуу органдарына олуттуу таасир этерин көрсөттү. Жер бетиндеги озон, токой өрттөрүнүн түтүнү жана майда бөлүкчөлүү заттардын жогорку концентрациялары дем алуу белгилеринин күчөшү жана астма менен хроникалык обструктивдүү өпкө оорусунун (ХОБЛ) курчушуна туруктуу байланыштуу. Атмосферадагы көмүр кычкыл газдын деңгээлинин жогорулашы жана мезгилдик циклдердин өзгөрүшү гүлдөө мезгилдеринин узактыгын жана күчтүүлүгүн жогорулатып, аба аллергендерине экспозицияны көбөйтөт. Ысык толкундар, катуу жаан-чачындар жана суунун кирүүсү сыяктуу экстремалдык аба ырайы окуялары ички жердеги көгөрүү менен дем алуу инфекцияларынын тобокелчилигин жогорулатат. Эң назик топтор – айрыкча балдар, кары-картаңдар жана социалдык жактан экономикалык жагынан мүмкүнчүлүгү чектелген коомдор – көбүрөөк таасирге дуушар болуп, оорулардын жүгү пропорциялык эмес жогору. Бул обзордун жыйынтыктары коомдук саламаттык сактоо планын түзүү жана клиникалык чечимдерди кабыл алуу үчүн илимий негизди түзүп, уязвимый топтордун климаттык дем алуу тобокелчилигин азайтууга багытталган максаттуу адаптация жана жеңилдетүү стратегияларын иштеп чыгууга жардам бериши мүмкүн

Негизги сөздөр: жер бетиндеги озон; бөлүкчөлүү заттар; чаңдуу бороон; аба аллергендери; хроникалык обструктивдүү өпкө оорусу; жеңилдетүү; адаптация

Воздушный кризис: усиливающиеся последствия изменения климата для дыхательной системы

Гавхарои Умурзакова
Старший преподаватель
Ошский государственный университет
723500, ул. Ленина 331, г. Ош, Кыргызская Республика
https://orcid.org/0000-0003-1580-1129

Айгуль Момунова
Кандидат биологических наук, доцент
Ошский государственный университет
723500, ул. Ленина 331, г. Ош, Кыргызская Республика
https://orcid.org/0000-0003-1917-0504

Маурья Алок
Студент
Ошский государственный университет
723500, ул. Ленина 331, г. Ош, Кыргызская Республика

Тивари Анмол
Студент
Ошский государственный университет
723500, ул. Ленина 331, г. Ош, Кыргызская Республика

Аннотация. Изменение климата все в большей степени признается серьезной угрозой для здоровья органов дыхания, что делает необходимым понимание того, как изменяющиеся условия окружающей среды влияют на функцию легких и структуру респираторных заболеваний. Целью данного обзора являлось обобщение современных научных данных о влиянии повышения температуры, изменения погодных условий и ухудшения качества воздуха на рост глобального бремени респираторных заболеваний. Был проведен всесторонний анализ современной рецензируемой научной литературы, включая эпидемиологические исследования, систематические обзоры и отчеты международных организаций здравоохранения. Данные о климатически обусловленных факторах окружающей среды анализировались в сопоставлении с зарегистрированными тенденциями показателей респираторного здоровья. Проанализированные данные засвидетельствовали о том, что климатически обусловленные изменения окружающей среды оказывают значительное влияние на здоровье органов дыхания. Повышенные концентрации приземного озона, дыма лесных пожаров и мелкодисперсных твердых частиц устойчиво ассоциированы с усилением респираторных симптомов и учащением обострений бронхиальной астмы и хронической обструктивной болезни легких (ХОБЛ). Повышение уровня углекислого газа в атмосфере и изменения сезонных циклов способствуют удлинению и усилению сезонов пыления, увеличивая воздействие аэроаллергенов. Экстремальные погодные явления, включая волны жары, интенсивные осадки и наводнения, способствуют росту плесени в помещениях и повышают риск респираторных инфекций. Наиболее уязвимые группы населения, особенно дети, пожилые люди и социально неблагополучные сообщества, несут непропорционально более высокое бремя заболеваний вследствие большей экспозиции и ограниченных адаптационных возможностей. Результаты данного обзора формируют научную основу для планирования мер общественного здравоохранения и клинического принятия решений, а также могут способствовать разработке целевых стратегий смягчения и адаптации, направленных на снижение климатически обусловленных респираторных рисков среди уязвимых групп населения

Ключевые слова: приземный озон; твёрдые частицы; пыльные бури; аэроаллергены; хроническая обструктивная болезнь лёгких; смягчение последствий; адаптация