



IMPACT OF SOLAR RADIATION AND HIGH TEMPERATURES ON WORKERS' HEALTH

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Annotatsiya

The aim of this literature review was to systematically analyze contemporary scientific evidence regarding the effects of solar radiation and high temperatures on the health of outdoor workers. Scientific articles published between 2015 and 2025 were retrieved and analyzed from the PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar databases. The findings indicate that exposure to elevated temperatures and ultraviolet radiation is associated with heat stress, dehydration, chronic kidney disease, cardiovascular disorders, dermatological pathologies, and reduced work productivity. In the context of climate change, the necessity of improving preventive and occupational hygiene measures to protect workers' health has been identified.

Kalit so'zlar: solar radiation, ultraviolet radiation, heat stress, high temperature, workers' health, occupational risk factors, dehydration, chronic kidney disease, climate change, occupational hygiene.

Introduction. Climate change has emerged as one of the most significant global challenges of the twenty-first century, exerting an increasingly profound impact on human health, occupational performance, and economic stability. Over recent decades, the continuous rise in the Earth's average surface temperature has led to a substantial increase in the duration, frequency, and intensity of heatwaves [1,2]. Under such conditions, workers engaged in outdoor activities or employed in high-temperature industrial environments are increasingly exposed to excessive heat loads and the harmful effects of solar radiation [3,4].

According to the International Labour Organization (ILO), more than 70% of the global workforce is exposed to hazardous heat conditions at least once annually, affecting approximately 2.4 billion individuals worldwide [5]. Estimates suggest that exposure to high temperatures contributes to more than 22.8 million occupational injuries and over 18,000 deaths each year [5,6]. These figures highlight the issue as not only a medical concern but also a significant socioeconomic challenge.

Solar radiation exerts multifaceted effects on the human body. The ultraviolet (UV) component of the solar spectrum has biologically active effects on the skin and ocular tissues, inducing various photochemical reactions [7]. While short-term intensive exposure may result in sunburn, photodermatitis, and acute ocular injuries, prolonged exposure can contribute to the development of skin cancer, cataracts, and immune system dysfunction [8,9]. According to the World Health Organization (WHO), diseases associated with ultraviolet radiation account for a considerable proportion of the global burden of disease [10].

Exposure to high temperatures activates the body's thermoregulatory mechanisms. To maintain normal body temperature, physiological responses such as increased sweating and enhanced peripheral blood circulation occur [11]. However, when heat load exceeds the body's adaptive capacity, dehydration, electrolyte imbalance, cardiovascular strain, and impairment of central nervous system function may develop [12,13]. Consequently, pathological conditions including heat cramps, heat exhaustion, and heat stroke can occur [14].

Recent epidemiological studies have demonstrated that exposure to high temperatures is associated not only with acute health effects but also with long-term adverse health outcomes. In particular, increased incidences of chronic kidney disease, cardiovascular disorders, and respiratory diseases have been reported among workers employed in agriculture, construction, metallurgy, transportation, and road infrastructure sectors [15–18]. Researchers attribute these findings to recurrent episodes of dehydration, heat stress, and oxidative stress [19].

Heat stress also has a substantial impact on occupational productivity. According to findings from several meta-analyses, workplace temperatures exceeding optimal levels contribute to reduced physical work capacity, shortened working hours, and an increased frequency of occupational errors [20–22]. Some projections estimate that by 2030, heat stress could result in the loss of more than 80 million full-time equivalent jobs globally [23].

The increasing frequency of hot days associated with climate change has become a significant concern for Central Asian countries, including the Republic of Uzbekistan [24]. During the summer months, ambient temperatures in Uzbekistan frequently reach 40–45°C or higher, while solar radiation intensity remains elevated throughout much of the year [25]. These environmental conditions represent an additional occupational risk factor for outdoor workers, particularly those employed in construction, agriculture, municipal services, and traffic police operations [26].

Although numerous scientific studies have investigated the mechanisms, health consequences, risk factors, and preventive measures associated with solar radiation and heat exposure among workers, there remains a need for systematic synthesis and critical evaluation of the available evidence based on contemporary scientific data [27–30]. Therefore, the present literature review aims to analyze the existing scientific evidence regarding the impact of high temperatures and solar radiation on workers' health.

Objective. To systematically analyze contemporary scientific evidence regarding the impact of solar radiation and high temperatures on workers' health.

Materials and Methods. This study was conducted as a literature review. Scientific publications were retrieved from the PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar databases. Articles published between 2015 and 2025, primarily in international scientific journals ranked within the Q1 and Q2 quartiles, were selected for inclusion. The literature search was performed using the keywords “occupational heat stress,” “solar radiation,” “workers’ health,” “heat exposure,” “climate change,” and “occupational diseases.” Selected studies were screened according to the PRISMA guidelines and subsequently evaluated through qualitative and content-based analysis.

Results. Pathophysiological Effects of Thermal Stress and Hyperthermia.

The reviewed literature indicates that when ambient temperatures exceed the thermoregulatory capacity of the human body, core body temperature rises above 38°C, resulting in heat stress [1]. At the cellular level, hyperthermia stimulates the synthesis of heat shock proteins (HSPs), which serve as protective mechanisms against thermal injury. However, prolonged heat exposure contributes to endothelial damage and may trigger a systemic inflammatory response syndrome (SIRS) [2].

Among outdoor workers employed in the agricultural and construction sectors, elevated body temperature is frequently accompanied by chronic dehydration. Studies have demonstrated that a loss of more than 2% of body weight during a work shift is associated with impaired cognitive performance, reduced concentration, and a 35% increase in the risk of occupational injuries [3].

Solar Radiation (UV Exposure) and Dermatological and Ophthalmological Disorders. Ultraviolet radiation (UV-A and UV-B) represents one of the most significant occupational carcinogenic hazards for outdoor workers. Long-term exposure to solar radiation substantially increases the risk of developing basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma [4].

Global studies have reported a strong association between outdoor occupational activities and the incidence of non-melanoma skin cancer (NMSC) [5]. The adverse effects of solar radiation and heat exposure across different occupational sectors are summarized in Table 1.

Table 1.
Adverse Effects of Heat Stress and Ultraviolet Radiation Among Workers in Different Occupational Sectors [6–8]

Occupational Sector	Major Risk Factors	Observed Health Outcomes and Pathologies	Relative Risk (RR) / Odds Ratio (OR)
Agriculture	Heat stress, direct UV exposure, dehydration	Chronic kidney disease of unknown etiology (CKDu), acute heat stroke, skin hyperpigmentation	RR = 2.1 (for kidney disorders)
Construction	Elevated WBGT index, reflected solar radiation	Cognitive dysfunction, occupational injuries, cataracts, squamous cell carcinoma	RR = 1.8 (for cataracts)
Road Construction / Municipal Services	Thermal radiation combined with asphalt surface heat	Cardiovascular strain, acute kidney injury, photodermatoses	OR = 2.4 (for hypertension-related complications)

Chronic Kidney Disease of Unknown Etiology (CKDu) and Nephrotoxic Consequences

Epidemiological studies conducted over the past decade have identified a direct association between strenuous physical work under high-temperature conditions and chronic kidney disease of unknown etiology (CKDu) [9]. When workers fail to maintain adequate hydration during work shifts, renal tubular ischemia and hyperuricemia may develop, contributing to progressive kidney injury.

Longitudinal analyses have demonstrated that when the Wet Bulb Globe Temperature (WBGT) exceeds 32°C, glomerular filtration rate (GFR) declines significantly. Repeated episodes of heat-related renal stress may eventually result in irreversible nephropathy [10,11].

Cardiovascular Alterations and Mortality Risk. Heat exposure imposes a substantial burden on the cardiovascular system, primarily through peripheral vasodilation. This physiological response leads to an increase in heart rate, often reaching 110–130 beats per minute (tachycardia), accompanied by an elevation in cardiac output [12].

Among workers with pre-existing cardiovascular diseases, the failure of these compensatory mechanisms has been associated with a 28% increase in the risk of myocardial infarction and stroke during heatwave periods [13,14].

Table 2.

Relationship Between Wet Bulb Globe Temperature (WBGT) and Physiological Responses in Workers [15–17]

WBGT (°C)	Maximum Recommended Continuous Working Time	Average Dehydration Rate (L/h)	Change in Heart Rate (bpm)	Risk of Subsequent Complications
< 26.0	No restrictions	0.3–0.5	Baseline (±5)	Minimal risk
26.0–29.9	45 min/hour	0.7–1.0	+15–20	Heat rash, muscle cramps
30.0–32.2	30 min/hour	1.2–1.5	+25–40	Acute fatigue, cognitive decline
> 32.2	Emergency work only	>1.8	>50 (critical)	Heat stroke, syncope-related injuries

Decline in Work Productivity and Economic Losses. The increase in ambient temperatures resulting from climate change has substantial consequences not only for human health but also for global labor productivity. Productivity losses associated with heat stress are largely attributable to workers' self-protective behavioral responses, including reduced work intensity and more frequent rest breaks [18,19].

Modeling studies have demonstrated that physical work capacity may decline by up to 50% when ambient temperatures exceed 34°C [20]. Consequently, many developing countries and regions characterized by hot climates are experiencing significant reductions in gross domestic product (GDP) due to heat-related productivity losses [21].

Discussion. *Thermoregulatory Failure and Systemic Pathophysiological Mechanisms.* The findings of the present review indicate that the synergistic effects of elevated ambient temperatures and direct solar radiation can rapidly overwhelm the

body's adaptive and compensatory mechanisms. As reported by Kjellstrom et al. [1], an increase in core body temperature above 38°C represents the threshold at which thermoregulatory dysfunction begins to develop among occupationally exposed populations. According to the meta-analysis conducted by Flouris et al. [2], cellular and molecular alterations, particularly insufficient heat shock protein (HSP) responses, contribute to increased endothelial membrane permeability. This process may subsequently trigger intravascular coagulation disturbances, including disseminated intravascular coagulation (DIC), and activate systemic inflammatory response syndrome (SIRS).

Clinically, this pathophysiological cascade manifests as a pronounced decline in cognitive performance among outdoor workers [3]. Reduced attention span and impaired motor coordination should not be regarded merely as symptoms of fatigue but rather as indicators of mild hyperthermia-induced cerebral ischemia. This mechanism provides a fundamental explanation for the observation that occupational injury rates in the construction and infrastructure sectors frequently peak during the afternoon hours, particularly between 14:00 and 16:00.

Occupational Nephropathies: The CKDu Epidemic and the Hydration Paradox

One of the most important findings of this literature review is that climate-related chronic kidney disease of unknown etiology (CKDu) differs fundamentally from traditional forms of chronic kidney disease. Studies conducted among agricultural communities in Central America and South Asia have demonstrated that CKDu develops largely in the absence of conventional risk factors such as diabetes mellitus and arterial hypertension [9,10]. Instead, prolonged occupational heat exposure and recurrent dehydration episodes, characterized by a loss of approximately 2% of body weight during a work shift, contribute to subclinical ischemic injury of the renal medulla [3,11].

The study conducted by Wesseling et al. [11] among sugarcane workers revealed the so-called hydration paradox. Even when workers consume adequate amounts of plain water, the replacement of electrolytes lost through sweating, particularly sodium and potassium, remains insufficient. As a result, hyponatremia and intracellular dehydration may develop, further exacerbating renal injury. When the Wet Bulb Globe Temperature (WBGT) exceeds 32°C, the acute decline in glomerular filtration rate (GFR) is associated with activation of vasoactive hormonal pathways, particularly the renin–angiotensin–aldosterone system, as well as uric acid crystallization within renal tissues [10]. Over years of occupational exposure, these pathological processes may progress to irreversible tubulointerstitial fibrosis. This complication represents a particularly relevant epidemiological concern for agricultural and industrial workers operating under the hot and arid climatic conditions of Central Asia.

Cardiovascular Strain and the Consequences of Heatwaves. The studies analyzed in this review indicate that the increase in cardiovascular mortality observed during heatwave periods—reaching up to 28% in some populations—is primarily attributable to the redistribution of peripheral hemodynamics [12,13]. To facilitate heat dissipation, blood flow is redirected from vital internal organs toward the skin through peripheral vasodilation. Consequently, heart rate may increase by as much as 40 beats per minute, accompanied by a substantial elevation in cardiac output [12,16].

According to Bunker et al. [14], older workers (>45 years) and individuals with comorbid conditions, including subclinical atherosclerosis and arterial hypertension, are particularly vulnerable to this cardiometabolic burden. Under conditions of markedly increased myocardial oxygen demand, dehydration-induced increases in blood viscosity may further promote coronary thrombosis and substantially elevate the risk of acute myocardial infarction. Thus, dehydration acts as an important cofactor amplifying the cardiovascular hazards associated with occupational heat exposure.

Dermatological Exposure and Mutagenic Effects of Solar Radiation. When discussing the effects of ultraviolet radiation (UV-A and UV-B), it is important to emphasize that outdoor workers receive, on average, two to three times greater annual UV exposure than indoor workers [7]. The systematic review conducted by Schmitt et al. [4] demonstrated a clear dose–response relationship between cumulative occupational outdoor exposure and the development of squamous cell carcinoma (RR > 1.8) as well as basal cell carcinoma.

At the molecular level, UV-B radiation directly damages pyrimidine bases within DNA strands, leading to the formation of cyclobutane pyrimidine dimers (CPDs) [22]. If the nucleotide excision repair (NER) pathway fails to effectively remove these lesions, mutations may accumulate within the p53 tumor suppressor gene, thereby creating favorable conditions for malignant transformation [23]. Based on this well-established pathogenetic mechanism, John et al. [5] advocated for the inclusion of non-melanoma skin cancer (NMSC) in the official list of occupational diseases in several European countries.

This risk is further amplified among workers operating near highly reflective surfaces, such as concrete structures, metal constructions, and asphalt pavements, where reflected ultraviolet radiation substantially increases cumulative exposure doses [6,8]. Such occupational settings create conditions in which the carcinogenic effects of solar radiation become particularly pronounced, underscoring the necessity for comprehensive photoprotection strategies and occupational health interventions.

Labor Economics and Preventive Adaptation Strategies. Rising temperatures represent not only a medical and public health concern but also a crisis affecting global and regional economic performance. Modeling studies conducted by Dunne et al. [18] suggest that climate warming has already reduced global labor capacity by approximately 10%. This phenomenon is particularly evident under conditions where ambient temperatures exceed 34°C, resulting in reductions of physical work productivity of up to 50% [20]. In response to excessive heat exposure, workers instinctively adopt self-preservation behaviors, commonly referred to as pacing, by reducing work intensity or increasing the frequency of rest periods. Although these behavioral adaptations are physiologically protective, they inevitably contribute to substantial economic losses through decreased labor efficiency and productivity [19,21].

Based on the findings and scientific discussions derived from this systematic literature review, the following conclusions can be drawn.

Conclusion

The findings of this review confirm that, under conditions of climate change, exposure to high temperatures (thermal stress) and solar ultraviolet radiation

constitutes a multifaceted, systemic, and high-risk occupational hazard for outdoor workers. Analysis of global scientific evidence indexed in the Scopus database demonstrates that adverse occupational microclimatic conditions contribute not only to acute heat-related illnesses and occupational injuries but also to the development of irreversible chronic pathologies affecting multiple organ systems.

1. Multifactorial pathophysiological responses to heat exposure substantially increase occupational health risks. Elevation of core body temperature above 38°C initiates systemic inflammatory responses (sirs) at both cellular and vascular levels. The resulting subclinical cerebral ischemia contributes to cognitive impairment, reduced attention, and diminished psychomotor performance, leading to an approximately 35% increase in the risk of occupational injuries.

2. Prolonged heavy physical work under hot environmental conditions contributes to the development of chronic kidney disease of unknown etiology (ckdu), a distinct clinical entity that occurs independently of traditional metabolic risk factors such as diabetes mellitus and hypertension. Consumption of plain water alone during work shifts is often insufficient to restore electrolyte balance. Consequently, recurrent episodes of renal tubular ischemia may progressively evolve into irreversible renal dysfunction and chronic kidney failure.

3. Long-term outdoor occupational activity exposes workers to annual ultraviolet radiation doses that are approximately two to three times higher than those experienced by indoor workers. At the cellular level, uv-b radiation induces direct dna damage and promotes mutations within the p53 tumor suppressor gene. These molecular alterations substantially increase the risk of non-melanoma skin cancer (nm-sc), with reported relative risks exceeding 1.8 among chronically exposed occupational groups.

4. Environmental temperatures exceeding a wbgt threshold of 34°C activate protective behavioral adaptations, including work pacing and increased rest periods. While these responses reduce the likelihood of acute heat-related illness, they may decrease physical work productivity by up to 50%. As a consequence, heat exposure has become an increasingly important determinant of economic losses, contributing to reductions in labor output, industrial efficiency, and gross domestic product (gdp), particularly in developing countries and regions characterized by hot climatic conditions.

5. The available evidence highlights the urgent need for comprehensive occupational health interventions, including heat-stress management programs, optimized hydration and electrolyte replacement strategies, ultraviolet radiation protection measures, climate-adaptive workplace policies, and continuous health surveillance of vulnerable worker populations. Such measures are essential for safeguarding workers' health and maintaining labor productivity in the face of ongoing global climate change.

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