

# Bulletin n°36

## Veille thermique

### Période : avril 2026

#### Objectifs :

L'INRS est de plus en plus sollicité sur des questions concernant les activités en entreprise par forte chaleur : les activités en extérieur, l'été en période de canicule, mais aussi les activités en intérieur, dans des lieux aux conditions thermiques extrêmes. L'objectif de cette veille est de se tenir informé sur ces thématiques, dans une période où la problématique thermique croît avec les changements climatiques.

*La bibliographie extraite de la base de données INRS-Biblio, permet la consultation des ressources en version PDF.*

*Les liens mentionnés dans le bulletin donnent accès aux documents sous réserve d'un abonnement à la ressource.*

*La validation des informations fournies (exactitude, fiabilité, pertinence par rapport aux principes de prévention, etc.) est du ressort des auteurs des articles signalés dans la veille. Les informations ne sont pas le reflet de la position de l'INRS.*

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## EPI, matériaux protecteurs/réchauffants

H. P. Gao.

**A comprehensive review on the influence of protective clothing and environmental conditions on firefighter heat stress.**

RESEARCH JOURNAL OF TEXTILE AND APPAREL. 2026.

<https://doi.org/10.1108/RJTA-06-2025-0137>

*Purpose* Firefighters must wear thick and insulative protective clothing while doing strenuous work in hostile environments to protect them from thermal hazards. However, this significantly impedes the body's ability to dissipate heat, increasing the risk of heat stress. Most firefighter fatalities are caused by cardiac events, with heat stress being a leading contributing factor. Thus, this study aims to explore how ambient conditions and protective clothing structure may impact firefighter heat stress. *Design/methodology/approach* This review systematically examines the ambient environments firefighters encounter, structure of firefighter protective clothing, standards regulating heat strain performance and the influence of ambient factors on heat stress. Finally, recent endeavors to improve heat strain performance of firefighter protective clothing are discussed. *Findings* The study reveals that environmental conditions and the structure of turnout gear play significant roles in firefighter heat stress. It highlights key challenges in current protective clothing and provides insights that may guide the development of next-generation gear aimed at reducing heat stress and improving firefighter safety. *Originality/value* This paper offers a comprehensive overview of the most recent advancements in the field of firefighter heat stress, supporting future innovations in protective clothing design.

A. Sheth, A. Viramgami, M. Thakor, B. Modi, B. Bagepally, A. Kar, E. Ram, A. Dave and R. Balachandar.

**Occupational heat stress and the role of wearable cooling interventions: A systematic review and meta-analysis of physiological and perceptual outcomes.**

SCANDINAVIAN JOURNAL OF WORK ENVIRONMENT & HEALTH. 2026.

<https://doi.org/10.5271/sjweh.4294>

*Objective* Occupational heat stress, driven by high ambient temperatures, humidity, and radiant heat impairs health, safety, and productivity. Among the interventions for mitigating heat strain, wearable cooling technologies [eg, water/ice, phase-change materials (PCM), ventilated/evaporative garments] is increasingly used, but their comparative effectiveness remains unclear. This systematic review aimed to evaluate the effectiveness of wearable cooling intervention on physiological and perceptual outcomes during heat exposure. *Methods* Adhering to PRISMA guidelines (PROSPERO: CRD42025631559), we searched PubMed, Embase, and Scopus (February 2026) for randomized or non-randomized intervention trials among workers or acclimatized adults. Data were extracted as mean/standard deviation (or transformed equivalents) and pooled using random-effects meta-analysis. Heterogeneity (I<sup>2</sup>), small-study effects (Egger's test) and sensitivity/subgroup analyses of cooling modalities were performed. Risk of bias (RoB 2, ROBINS-I) and certainty (GRADE) were assessed. *Results* Sixty-nine studies were included in our review. Post-exposure, wearable cooling significantly reduced rectal temperature [mean difference (MD)-0.24 degrees C; 95% confidence interval (CI)-0.37--0.1; I<sup>2</sup>=43.91%], gastrointestinal temperature (MD-0.26 degrees C;-0.52--0.001; I<sup>2</sup>=98.13%), skin temperature (MD-1.14 degrees C;-1.85--0.42; I<sup>2</sup>=96.56%), and heart rate (MD-7.69 bpm;-11.22--4.15;

*I<sup>2</sup>=73.19%). Egger's tests suggested possible smallstudy effects for skin temperature and heart rate but not for core temperatures. Subgroup analyses indicated more consistent benefits with water/ice and PCM garments. Overall certainty ranged from low to very low due to risk of bias, inconsistency, and imprecision. Conclusions Wearable cooling attenuates physiological heat strain and improves thermal comfort, particularly via water/ice and PCM systems. Given high heterogeneity and low certainty, adequately powered, standardized, head-to-head trials are needed.*

W. R. Kinnaird, A. R. Moore, T. J. Oberther and A. M. Winkler.

### **Personal Protective Equipment Immediately Alters the Core-Skin Temperature Gradient in Recruit Firefighters.**

LIFE-BASEL. 2026;16(4).

<https://doi.org/10.3390/life16040671>

*The purpose of this study was to quantify the degree to which personal protective equipment (PPE) affects the core-skin temperature gradient in nine recruit firefighters attending fire academy. Participants wore a chest monitor and ingested a pill to continually measure skin and core temperature, respectively. PPE status was defined as periods during which participants were wearing full PPE (ON) and not wearing PPE (OFF). During the study, participants transitioned between PPE ON to PPE OFF seven times. These transition timepoints, defined as paired two-minute averages collected immediately before (PPE OFF) and shortly after (PPE ON) donning PPE, were analyzed to examine the immediate effects of PPE use. Factorial repeated-measures ANOVAs were used to assess the effects of PPE status, time, and their interaction on temperature gradient, core temperature, and skin temperature. There was a significant interaction effect on the temperature gradient ( $p < 0.001$ ), with higher gradients in the OFF condition compared to ON at timepoints 2-7. A significant interaction was observed for skin temperature with higher values in ON than OFF for timepoints 2-7 as well. There was no interaction ( $p = 0.445$ ) or main effect of PPE status ( $p = 0.906$ ) for core temperature. This study demonstrates that adding PPE significantly reduced the core-skin temperature gradient in recruit firefighters, largely due to increases in skin temperature.*

R. Maryam, H. E. Roman, R. Barni, A. A. Anceschi, A. Patrucco, K. Alexander, I. Levchenko and C. Riccardi.

### **Smart graphene oxide-based advanced textiles: A review of wearable smart clothing, personal thermal management, and sensor applications.**

CARBON. 2026;255.

<https://doi.org/10.1016/j.carbon.2026.121519>

*Graphene oxide-based textiles are rapidly advancing as multifunctional materials for personal thermal regulation, antibacterial protection, and wearable sensing. This review provides a brief overview of recent developments in the integration of graphene oxide (GO) into textile substrates, with a focus on the underlying mechanisms driving heat management and sensing capabilities. In thermal applications, we explore how GOmodified fibres leverage Joule heating and phase-change effects to dynamically regulate surface temperature while preserving mechanical integrity. In sensing technologies, GO's high surface area and tunable electronic properties enable improved sensitivity and rapid response in detecting strain, humidity, and biochemical markers. We also address key challenges, including scalable production, wash durability, and long-term environmental stability, offering insights into material optimization and integration strategies. By critically examining current progress and technological*

*hurdles, this review highlights the potential of GO-functionalized textiles to transform wearable systems, with promising applications in healthcare, environmental monitoring, and smart clothing.*

P. Sudalaimuthu, R. Sathyamurthy, P. Mehta and V. Rajendran.

### **Synergetic Effect of Rubber Sheet and Jute Cloth on Solar Thermal Evaporation From Inclined Solar Still: An Experimental Approach.**

HEAT TRANSFER. 2026.

<https://doi.org/10.1002/htj.70246>

*The low freshwater productivity of passive solar stills remains a major barrier to their widespread deployment in water-scarce regions. To address this limitation, the present study experimentally investigates the performance enhancement of an inclined solar still (ISS) using a bilayer absorber configuration composed of a rubber sheet and jute cloth. In this design, the rubber sheet serves as a sensible thermal energy storage and insulation layer, while the jute cloth functions as a hydrophilic porous wick to promote localized interfacial evaporation. Three configurations were tested under identical climatic conditions: a conventional ISS, an ISS with a rubber sheet, and an ISS with a combined rubber-jute bilayer absorber. Key performance parameters, including absorber, basin water, and cover temperatures, hourly distillate yield, and thermal efficiency, were measured and compared. The results show that incorporating the rubber sheet alone increased the daily freshwater yield and average thermal efficiency by 48.05% and 48.24%, respectively, compared with the conventional ISS, due to improved heat retention and delayed thermal release. The bilayer rubber-jute configuration delivered the best performance, achieving a maximum absorber temperature of , sustained elevated water temperatures during postpeak solar hours, and a daily freshwater yield of , corresponding to a 70.31% improvement over the baseline ISS. The average thermal efficiency increased from 23.34% to 39.75%, confirming a nonadditive, synergistic enhancement arising from the coupled action of thermal storage and wick-assisted evaporation. Overall, the study demonstrates that integrating low-cost, locally available materials into a bilayer absorber structure can significantly improve the thermal performance and productivity of ISSs, offering a simple, scalable, and sustainable solution for decentralized solar desalination applications.*

## Maladies liées à la chaleur

E. M. Rojo and H. B. Bosworth.

### **Navigating the heat: implementation challenges and opportunities for heat alert communication and rural health data infrastructure.**

FRONTIERS IN PUBLIC HEALTH. 2026;14.

<https://doi.org/10.3389/fpubh.2026.1801198>

*Extreme heat is the most significant climate threat to public health, disproportionately impacting marginalized groups, including outdoor workers, older adults, and low-income rural populations. While the physiological consequences of heat-related illness-ranging from cardiovascular strain to acute kidney injury-are well-documented, a critical gap remains in the equitable implementation of mitigation strategies. This paper examines North Carolina as a case study due to its proactive leadership in heat-health mitigation, examining the evolution of the state's Heat Health Alert System and the NC DETECT surveillance platform. North Carolina is well-positioned to pioneer a multi-modal "push" communication strategy, leveraging the ubiquity of smartphone technology and Wireless Emergency Alerts to provide "just-in-time" guidance to high-risk outdoor workers and rural residents. Simultaneously, the state can strengthen its robust surveillance infrastructure by integrating data from non-traditional care sites, such as farmworker clinics, and standardizing occupational data collection. These advancements would transform existing systems into a comprehensive, community-informed model of resilience. By expanding communication modalities and data inclusivity, North Carolina offers a scalable framework for translating meteorological risk into actionable, equitable policy-ensuring that advancements in climate preparedness protect and empower the most vulnerable populations.*

L. van Selm, C. Voorhis, S. Williams, D. Izuzquiza-Regalado, S. Notario-Gallego, S. Diop, S. Evangelidou, E. Briones-Vozmediano and A. Requena-Méndez.

### **Lived experiences of heat stress among migrant agricultural workers in Spain: a qualitative study.**

INTERNATIONAL JOURNAL FOR EQUITY IN HEALTH. 2026;25(1).

<https://doi.org/10.1186/s12939-026-02850-x>

*Background Agricultural workers face high heat stress risk due to environmental and working conditions. Migrant agricultural workers (MAW) are especially vulnerable due to additional structural factors including irregular migratory status and high economic needs. Our study explores the lived experiences of occupational heat stress among MAW and its impact on health. Methods An interpretive, qualitative design was employed. Through purposive sampling we selected MAW in Almeria, Lleida, and Huelva for semi-structured interviews. Interviews were audio-recorded, transcribed, and analyzed using reflexive thematic analysis. Results Thirty interviews were conducted with six female and 24 male MAW, predominantly from sub-Saharan and North-Africa. The findings were organized into five overarching themes: Working under the sun: exposure and embodiment; The dilemma of heat: work or wellbeing; Employers efforts to protect workers: a regime of discretion; Protecting oneself from the heat: navigating limited agency; and non-work-related factors: compounding vulnerabilities. Participants described discomfort and heat-related illness symptoms. Protective strategies included drinking water, wearing appropriate clothing, and taking breaks, but pressure from supervisors to maintain a fast work pace and limit breaks often compromised these protective efforts. Employer discretion largely determined access to heat-protective measures. Participants also reported limited ability to cool down after work due to high indoor temperatures in*

*substandard housing. Conclusions Occupational heat risk for MAW extends beyond environmental factors and is amplified by socioeconomic inequities. Implementation of more specific and enforceable heat-protection measures and improved enforcement mechanisms, alongside mandated improvements to working and living conditions, are needed to reduce heat-related health risks.*

S. Lahri.

### **The health effects of extreme heat.**

AFRICAN JOURNAL OF PRIMARY HEALTH CARE & FAMILY MEDICINE. 2026;18(1).

<https://doi.org/10.4102/phcfm.v18i1.5372>

*Extreme heat is a significant direct health threat from climate change, with rising temperatures and frequent heatwaves increasingly stressing communities and health services across Africa. High baseline temperatures, widespread outdoor labour, limited cooling access and structural vulnerabilities heighten population exposure. The physiological impacts are severe: from extreme heat overwhelming thermoregulation, leading to dehydration, cardiovascular strain, direct cellular injury and potentially rapid progression to heat exhaustion, to the most severe and dangerous form, heat stroke, which is a medical emergency characterised by a core body temperature > 40 degrees C and central nervous system dysfunction such as confusion, seizures or coma, leading to multiorgan dysfunction. Heat also exacerbates chronic conditions like heart failure, asthma and kidney disease. Beyond clinical presentations, community-level evidence shows heat causes sleep disturbance, irritability and significant reductions in productivity. Vulnerable groups include infants, older adults, pregnant women, individuals with chronic diseases and outdoor workers. Maternal and neonatal health is particularly at risk, with links to preterm birth, stillbirth and hypertensive disorders. Primary health care is central to addressing this threat through early recognition, prompt cooling, hydration, medication review and tailored counselling for low-resource settings and environments. A proactive integration of heat-health interventions into routine primary care is therefore critical to building climate-resilient health systems and safeguarding vulnerable populations.*

## Outils et capteurs de mesure

J. J. Meng, J. R. Li, C. H. Li, X. K. Li, E. P. Zhao, H. M. Fang, L. J. Nie, B. Fu, J. H. Zhang and H. W. Zhao.

**In-situ quantitative characterization of thermal strain based on laser ultrasonic technology under high-temperature conditions.**

INTERNATIONAL JOURNAL OF THERMAL SCIENCES. 2026;227.

<https://doi.org/10.1016/j.ijthermalsci.2026.110968>

*Laser ultrasonic technology has gained extensive application in harsh working conditions owing to the optical merits of non-contact, remote in-situ testing and the acoustic advantage of high detection accuracy. This study proposes a laser ultrasonic-based technique for quantitative characterization of thermal strain at elevated temperatures, successfully achieving accurate measurements across multiple materials from 25 degrees C to 500 degrees C. The characterization that the main propagation direction of the longitudinal wave excited by the pulsed laser source coincides with the thermal strain orientation enhances the practical applicability of longitudinal wave-based detection methodologies. The direct correlation between thermal strain and time-of-flight (TOF) of longitudinal waves during heating establishes the fundamental rationale for TOF-based thermal strain characterization. To address the temperature-dependent variation of longitudinal wave velocity affecting TOF analyses, numerical simulations are implemented to calculate velocities of longitudinal waves at different temperatures for TOF correction. Consequently, a relative TOF parameter is developed as a quantitative indicator of thermal strain. The actual thermal strains of each type of material are obtained using the standard push-rod method to calibrate laser ultrasonic measurements. The designed contralateral concentric detection scheme is adopted to capture actual longitudinal wave TOF at various temperatures, enabling the construction of a response model correlating relative TOF with thermal strain. Least-squares fitting reveals linear correlations between relative TOF and thermal strain for all tested materials, thereby validating the effectiveness of this laser ultrasonic characterization methodology. This research provides a promising detection strategy for in-situ online measurement of thermal strain under high-temperature conditions.*

## Travail dans une ambiance thermique extrême

R. E. Wowor, D. V. D. Doda, V. R. Danes, V. Simangunsong, W. B. S. Joseph, A. Arshad and M. Pangaribuan.

**Ventilation effects on particulate matter, heat stress, and respiratory health biomarkers during commuting.**

ATMOSPHERIC POLLUTION RESEARCH. 2026;17(5).

<https://doi.org/10.1016/j.apr.2025.102866>

*Daily commuting in enclosed vehicles exposes individuals to varying levels of air pollution and heat stress, which may influence respiratory health. This study aimed to quantify how ventilation settings affect PM exposure, heat stress, and short-term respiratory responses. A four-day field study was conducted with four healthy female students commuting in a passenger car under four different ventilation conditions. PM ( $\geq 0.3$  to  $\geq 5.0 \mu\text{m}$ ) and HSI (WBGT,  $T_g$ ,  $T_w$ ,  $T_a$ , RH, HI) were recorded every minute, while RHI (FEV<sub>0.75</sub>), FEV<sub>1</sub>, FVC, PEF, FEF<sub>25-75</sub>), and relevant ratios) were measured hourly. Wilcoxon rank-sum tests and effect sizes were used for statistical analysis. PM concentrations and HSI values increased significantly in more open ventilation settings, with the highest levels observed in Scenario 4. For instance, PM( $\geq 0.3$ ) increased from 2853 & times; 10(3) ppm(3) in Scenario 1 to 8893 & times; 10(3) ppm(3) in Scenario 4 ( $p < 0.001$ ,  $r = 0.64$ ). Similarly, WBGT increased from 24.29 degrees C to 33.14 degrees C ( $p < 0.001$ ,  $r = 0.64$ ). Several RHI values, including FEV<sub>1</sub>, FVC, and FEF<sub>25-75</sub>), decreased significantly in scenarios with higher environmental exposure, particularly Scenario 4. Scenarios involving open windows and no AC resulted in the poorest air quality and highest heat exposure, along with reduced lung function. In hot, traffic-dense urban settings, using recirculated air conditioning may serve as a practical strategy to improve in-cabin air quality and thermal comfort. This study is among the few to simultaneously assess particulate exposure, heat stress, and respiratory responses across multiple ventilation settings in real commuting conditions.*

## Travail par fortes chaleurs et périodes de canicule

S. A. Mirhosseini, R. D. Chang, H. Omrany, Y. Zou and Y. Liu.

### Application of machine learning technologies in predicting severity of heat-related illnesses among construction workers.

SMART AND SUSTAINABLE BUILT ENVIRONMENT. 2026.

<https://doi.org/10.1108/SASBE-02-2025-0101>

*Exposure to extreme heat poses significant health risks for construction workers due to multiple reasons. However, research on heat-related illnesses (HRIs) in this sector has often relied on statistical methods, limiting insights into causal mechanisms and feature interrelations. This study addresses this gap by employing machine learning (ML) techniques to predict the severity of HRIs (fatal vs non-fatal) and identify critical contributing factors. Design/methodology/approach A total of 370 Occupational Safety and Health (OSHA) HRI reports are analyzed using natural language processing (NLP) to extract key features. These features are combined with climatic and non-climatic variables. Four ML algorithms - random forest, extreme gradient boosting, k-nearest neighbors and logistic regression - are applied to classify HRIs as fatal and non-fatal. Feature importance and dependencies are explored using SHAP (SHapley Additive exPlanations). Findings The random forest model achieves the highest accuracy at 70%. Employers' negligence and workers aged over 35 years are key human-centric factors in fatal HRIs. Humid subtropical and hot-summer Mediterranean climate zones are the most hazardous environmental factors. The results suggest that small-scale projects with limited budgets, renovation projects and building projects (residential/commercial) are the key contributing project-related features in the severity of HRIs. Originality/value This study is among the first attempts to investigate HRI reports specifically in the construction industry by using artificial intelligence techniques. The findings emphasize the need for tailored heat stress prevention programs in construction projects based on their characteristics.*

H. Y. Chen, J. C. Lung, S. Y. Lin, H. Y. Wu, Y. R. Huang, P. W. Li, L. W. Liu and S. W. Tsai.

### Comparative accuracy of instrumented and app-based WBGT for heat-stress screening in agricultural environments in Taiwan.

JOURNAL OF OCCUPATIONAL AND ENVIRONMENTAL HYGIENE. 2026.

<https://doi.org/10.1080/15459624.2026.2657310>

*This pilot research assessed the reliability of wet-bulb globe temperature (WBGT) screening tools and examined how different microenvironments might affect worker-level WBGT in Taiwanese agriculture. In July 2024, WBGT was recorded at six locations using a QUESTemp monitor with sensors positioned at the head, abdomen, and ankle (weighted 1:2:1), along with portable Kestrel and AZ (AZ) devices and the AIHA (R) app. The AZ devices were evaluated for within-site variations across various work environments, including soil, shade, ground-cover cloth, grassland, asphalt, and ridges. Agreement analyses and Bland-Altman plots were used to compare methods. Median WBGT values ranged in the low to mid-30s degrees C, with four sites having 50% or more of measurements at or above 32 degrees C. The Kestrel device demonstrated the closest agreement (bias +0.32 degrees C; RMSE 0.80 degrees C), the AZ device tended to underestimate (-0.94 degrees C; RMSE 1.28 degrees C), and the AIHA app showed the largest errors (bias -0.83 degrees C; RMSE 1.82 degrees C). Microenvironmental factors caused WBGT shifts between -1.25 and +2.87 degrees C, with decreases caused by working in shaded areas and increases caused by working in reflective ground covers. When screened against the*

operational WBGT benchmarks (30 degrees C and 32 degrees C), the QUESTemp monitor frequently recorded values at or above these thresholds, indicating high-heat conditions. However, the systematic underestimation by the wearable AZ device resulted in a significantly lower detection rate of the high-heat conditions, highlighting the risk of false-negative safety assessments when using uncorrected personal monitors. Overall, the portable/wearable Kestrel and AZ devices showed closer agreement with the QUEST than the weather-station-based app estimates. Given the limitations of regional weather data observed in this pilot study, effective heat-risk management in agriculture requires site-specific monitoring to account for microenvironmental variations, rather than relying solely on app-based estimates.

M. T. Ali, M. H. Rashid and M. Khalid.

### **Heat stress and thermal discomfort in construction: Implications for occupational safety and regulation.**

BUILDING AND ENVIRONMENT. 2026;294.

<https://doi.org/10.1016/j.buildenv.2026.114370>

*Heat stress (HS) significantly affects outdoor construction workers, increasing health, safety, and productivity risks, particularly in developing countries where the lack of formal regulations leads to unmanaged heat exposure and inadequate protective measures. Few studies have examined HS and thermal comfort (TC) at large spatial scales while considering variations across vertical positions on an hourly basis, leaving critical spatiotemporal patterns largely unaddressed. To fill these gaps, this study analyzes hourly meteorological data (2021-2024) and personal parameters during the summer months (April-May) across eight major urban cities in Bangladesh. HS, expressed as Physiological Equivalent Temperature (PET), and TC indices, including Predicted Mean Vote (PMV), Standard Effective Temperature (SET), and Predicted Percentage of Dissatisfied (PPD), were quantified for construction workers. Existing comfort-index methods were adapted for outdoor conditions by accounting for shortwave and longwave solar radiation, and the results were validated through stakeholder feedback. Meteorological parameters were stratified by occupational height to assess PET and PMV variations across the different levels at which construction workers perform their tasks, and spatial interpolation was employed to map national-scale distributions. Results indicate that In April, PET frequently exceeded 41 degrees C across most regions, with southern PMV values often surpassing 3.0, indicating extreme HS. Spatial analysis identified the southwest as the most vulnerable zone, where humidity exacerbated discomfort, whereas the northeast remained comparatively temperate. PET declined significantly with occupational height ( $R^2 = 0.95-0.99$ ; slope =  $-0.023$  to  $-0.029$  degrees C/m), and PMV values were consistently higher at lower elevations (0-30 m), with the sharpest changes in some regions. Peak heat hours occurred between 11:00 and 17:00, which suggest that early morning or late afternoon work can reduce heat stress while maintaining productivity. Stakeholder feedback confirmed the framework's relevance for understanding HS distribution and mitigation strategies.*

N. Khan, R. Houmsi, M. S. I. Ibrahim and S. Shahid.

### **Impact of heat stress on outdoor labor productivity in peninsular malaysia: a spatio-temporal assessment.**

NATURAL HAZARDS. 2026;122(8).

<https://doi.org/10.1007/s11069-026-08113-w>

*Understanding the influence of environmental factors on labor efficiency is crucial in regions with rising temperatures. This study investigates the impact of heat stress, measured using the Wet Bulb Globe Temperature (WBGT), on labor productivity in Peninsular Malaysia from 1959 to 2021 using hourly data from the European Centre for Medium-Range Weather Forecasts fifth-generation reanalysis (ERA5). The outdoor WBGT was estimated using the Liljegren method, and labor productivity was calculated using the ISO/DIS 7243 method by comparing actual WBGT values with WBGT limit reference values for three workload intensities: light, moderate, and heavy. The results reveal a strong negative correlation between WBGT and productivity. Productivity declined markedly during peak heat-stress hours (12:00-16:00) over the past 63 years, with heavy workloads most affected. The largest productivity losses occurred in the southern and southeastern coastal regions, exceeding 22% in some areas. When WBGT exceeded threshold values of 29.4 degrees C (light), 27.2 degrees C (moderate), and 25.8 degrees C (heavy), productivity declined by 16.8%, 13.5%, and 11.1% per 1 degrees C increase, respectively. Trend analysis showed that rising temperatures are the primary driver of increased productivity losses. The study proposes rescheduling work periods with an extended midday break, which could enhance productivity by 6.72% for light, 9.64% for moderate, and 10.25% for heavy workloads compared to current schedules. These findings highlight the urgent need for adaptive strategies to mitigate the impact of increasing WBGT on regional labor productivity.*

H. Keivanfard and C. Mullins-Jaime.

#### **Reducing heat stress in warehouse loading docks: Evaluation of a dual-fan air circulation intervention.**

JOURNAL OF SAFETY RESEARCH. 2026;97:334-9.

<https://doi.org/10.1016/j.jsr.2026.03.010>

*Background: Loading docks and trailers present high-risk environments for heat stress during summer months and heatwaves. Literature on heat risks in indoor and semi-indoor spaces such as warehouses is limited. While recognized as a top tier hazard control, there is also limited empirical support of ventilation controls for thermal stress in loading dock and warehouse spaces. This study evaluated whether a simple dual-fan circulation method, leveraging Archimedes, buoyant force, and convection principles, could reduce heat index values inside trailers compared to a conventional single-fan method. Methods: Data were collected from 100 trailers during peak summer months in a Midwestern warehouse. Temperature and humidity were recorded, and heat index values were calculated using the National Weather Service chart. Independent-samples t-tests and ANCOVA adjusting for outdoor ambient conditions were conducted. Results: The dual fan method significantly reduced trailer heat index compared to single fans,  $t(98) = 2.96$ ,  $p = 0.004$ , with a medium-to-large effect (Hedges'  $g = 0.59$ ). ANCOVA indicated that dual fans moderated the effect of outdoor temperature, explaining 43.7% of the variance in heat index (partial  $\eta^2 = 0.36-.38$ ). Conclusion: Findings demonstrate that dual-fan circulation is a low-cost, scalable engineering control that meaningfully reduces thermal stress in trailers and buffers against rising outdoor temperatures. These results support integrating simple engineering interventions into warehouse heat prevention programs to protect worker health and sustain productivity.*

J. W. Liu, Z. Z. Zhang, Y. Yang, J. X. Wang, J. Song, L. S. Jing, J. L. Li and H. Zhang.

#### **Study on the temporal and spatial characteristics, health risks, and targeted control strategies of volatile organic compounds (VOCs) exposure in China-specific indoor air.**

AIR QUALITY ATMOSPHERE AND HEALTH. 2026;19(4).

<https://doi.org/10.1007/s11869-026-01985-8>

*With rapid urbanization in China and evolving residents' lifestyles, indoor air quality (IAQ) has become a growing concern across various sectors of society. Among indoor pollutants, volatile organic compounds (VOCs) are ubiquitous contaminants with varied and complex sources, posing potential health risks that represent a pressing public health issue. This study aims to provide a systematic critical review of VOC exposure characteristics in China-specific indoor environments, evaluate their health risks through comparative analysis, and develop evidence-based control strategies. This study conducts a systematic review following PRISMA guidelines of peer-reviewed literature on indoor VOCs in China published between 2000 and 2024. We searched Web of Science, PubMed, CNKI, Wanfang, and VIP databases, ultimately including 246 studies meeting quality criteria. VOC concentration data from various indoor environments including residences, public spaces, and vehicles were systematically analyzed using meta-analytical techniques. Health risk assessments were synthesized using EPA-established methodologies adapted with China-specific exposure factors, focusing on both carcinogenic and non-carcinogenic risks. The analysis examined unique contributions of China-specific factors including building materials, household products, Chinese-style cooking, and human activities to indoor VOC emissions through an analytical framework linking sources, pathways, and receptors. The review reveals significant spatiotemporal heterogeneity in VOC concentrations within Chinese indoor environments, with substantial methodological considerations affecting reported values. Formaldehyde, benzene homologues, and TVOCs frequently exceed national standards, with exceedance rates reaching 88.29-96.43% in some residential areas. Meta-analysis shows formaldehyde concentrations demonstrate temperature-dependent emission following modified Arrhenius kinetics (activation energy = 45.2 +/- 3.8 kJ/mol), with summer levels 2.3 times higher than winter. Regional analysis reveals BTX concentrations in northeastern China exceed southern regions by 2-3 fold, correlating with heating degree days ( $r = 0.76$ ) and economic development indices ( $r = 0.68$ ). Health risk assessments indicate lifetime cancer risks exceed acceptable thresholds by 10-100 fold even at concentrations meeting national standards. Children show elevated vulnerability with adjusted odds ratios for asthma of 11.985 for formaldehyde exposure, substantially higher than Western populations. Occupational groups face extreme exposures, with renovation workers' cumulative cancer risk reaching 1.2 & times; 10(- 4). Mixture effects analysis reveals synergistic interactions increasing hazard indices by 40-90% above additive models. Indoor VOC pollution in China presents unique public health challenges requiring targeted interventions beyond Western models. The fundamental disconnect between regulatory compliance and health protection stems from standards based on odor thresholds rather than health endpoints, unique emission sources from rapid urbanization, and synergistic effects of complex mixtures. The study proposes an integrated control framework prioritizing source management (benefit-cost ratio = 4.0), ventilation optimization accounting for outdoor pollution trade-offs, advanced purification technologies, culturally-sensitive behavioral interventions, and tiered regulatory standards recognizing population vulnerability. Implementation requires coordinated multi-stakeholder engagement and recognition of China-specific exposure scenarios. Future research priorities include establishing long-term monitoring networks, assessing emerging VOCs, and developing cost-effective technologies adapted to Chinese conditions.*

H. Wang, J. Y. Wang, G. M. Li, Y. Y. Chi, M. S. Deng, K. W. Tham and C. H. Li.

**Uncovering hidden VOCs risks in metro halls: A non-targeted screening and health risk during extreme summer heatwaves.**

BUILDING AND ENVIRONMENT. 2026;294.

<https://doi.org/10.1016/j.buildenv.2026.114371>

*With accelerating urbanisation and intensifying climate change, metro systems have emerged as critical components of urban transportation infrastructure. However, the quality of indoor air within these environments, particularly under extreme weather conditions, remains insufficiently characterised. Of particular concern is the presence of volatile organic compounds (VOCs) in semi-enclosed metro halls, which poses latent public health risks. These risks are further exacerbated during recurrent summer heatwaves. Yet, previous investigations have predominantly focused on a narrow subset of target VOCs, such as benzene, toluene, ethylbenzene, and xylene (BTEX), thereby overlooking the broader chemical complexity and dynamic physiological exposure processes. To address this gap, the present study conducted non-targeted VOC screening in the metro halls in Zhengzhou, a representative city in central China experiencing high summer temperatures. Field sampling was carried out across ten typical metro stations using thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS), accompanied by the physiological monitoring of twenty volunteers. A total of 68 VOC species were identified, with aromatic hydrocarbons accounting for 29.41% of the total, dominating both detection frequency and concentration. Notably, compounds such as benzoic acid and acetophenone exhibited persistently high concentrations. Physiological data indicated significant increases in core body temperature and respiratory rate following heat exposure, resulting in a 17-23% elevation in VOC inhalation risk. These findings underscore the compounded risk of chemical and thermal exposure in metro environments and highlight the urgent need for thermally adaptive ventilation strategies and integrated health risk management within public transit systems.*

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#### **Unveiling the Effects of Climate Change on Construction Workers: A Systematic Literature Review.**

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*This article systematically reviews the impact of climate change and high temperatures on construction workers' health and safety, emphasizing their increased vulnerability to heat due to outdoor work conditions. Using PRISMA standards, the review categorizes studies into four types: experimental, medical, organizational, and review-focused. Key findings highlight the importance of preventive measures such as structured breaks in shaded areas, heat-adaptation strategies, and the development of targeted policies to address heat risks. The analysis reveals a notable gap in gender-based studies, suggesting that different responses to thermal stress across genders warrant further exploration to inform tailored interventions. Moreover, the article underscores the need for evolving regulatory frameworks to address the unique challenges posed by climate change on outdoor labor, with an emphasis on the construction sector. Through these findings, the review calls for comprehensive regulatory updates and targeted research to enhance worker safety, improve sector resilience, and support sustainable practices amidst escalating environmental stressors due to climate change.*

## Actualités avril 2026

- Travail par fortes chaleurs et périodes de canicule

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[D'après un sondage, 53% des salariés jugent leur entreprise mal préparée à la canicule.](#) Journaldeleconomie.fr, 7 avril 2026

[Bamako sous un dôme de chaleur : La capitale malienne face à un record de température en ce mois d'avril.](#) Maliactu.net, 8 avril 2026

[La FIFA adopte des mesures prises pour faire face aux canicules pendant la CM.](#) Lapresse.ca, 29 avril 2026

[Tokyo : les salariés invités à venir travailler en short pour économiser l'énergie.](#) Breizh-Info, 29 avril 2026

[Delhi sizzles at 42.3°C as peak power demand hits season's high,](#) Thetribuneindia.com, 28 avril 2026

- Maladies liées à la chaleur

[Le réchauffement climatique fragilise déjà notre santé,](#) Lefigaro.fr, 22 avril 2026

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[Inflammation may temporarily rise and increase risk of heat illness.](#) Physiology.org, 24 avril 2026

[Heat Stroke or Heat Exhaustion? AIIMS Doctor Explains Key Symptoms, How To Prevent.](#) Healthandme, 30 avril 2026