

Bulletin n°5

Veille thermique

Période : avril 2023

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.

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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Travail par période de canicule

S. A. R. Naqvi, K. Kar and S. Mishra.

Autonomous pre-conditioning and improved personalization in shared workspaces through data-driven predictive control.

ENERGY AND BUILDINGS. 2023;285.

<https://doi.org/10.1016/j.enbuild.2023.112897>

This paper studies the problem of indoor zone temperature control in shared workspaces equipped with heterogeneous heating and cooling sources with the goal of increased energy savings and environment personalization. Shared workspaces typically witness distinct, pre-scheduled intervals when they are occupied or are unoccupied. In this work, we develop indoor climate control strategies for each of these intervals. For the interval when the workspace is unoccupied, we propose multiple time-bound control strategies for pre-conditioning the workspace in preparation for a scheduled activity (Phase I). For the interval when the workspace is occupied, we propose a separate control strategy which enhances the thermal comfort of the occupants by harnessing the spatial differentiation of the thermal environment to satisfy the different temperature preferences of the individuals (Phase II). Utilizing a physical test-bed and data-driven model learning, we show that our proposed pre-conditioning strategies in Phase I are less computationally expensive than conventional model predictive control (MPC). For Phase II, we use a low complexity quadratic program to minimize the thermal discomfort experienced by individuals based on their temperature preferences. The experimental results show that for Phase I, the proposed control policies can save a significant amount of energy and achieve the desired mean temperature in the space fairly accurately. We further note that for Phase II, the control scheme can achieve a significant spatial differentiation in temperature towards satisfying the occupants' thermal preferences.(c) 2023 Elsevier B.V. All rights reserved.

J. Knox-Hayes, J. C. Osorio, N. Stamler, M. Dombrov, R. Winer, M. H. Smith, R. A. Blake and C. Rosenzweig.

The compound risk of heat and COVID-19 in New York City: riskscape, physical and social factors, and interventions.

LOCAL ENVIRONMENT. 2023.

<https://doi.org/10.1080/13549839.2023.2187362>

Climate change is disrupting the fundamental conditions of human life and exacerbating existing inequity by placing further burdens on communities that are already vulnerable. Risk exposure varies by where people live and work. In this article, we examine the spatial overlap of the compound risks of COVID-19 and extreme heat in New York City. We assess the relationship between socio-demographic and natural, built and social environmental characteristics, and the spatial correspondence of COVID-19 daily case rates across three pandemic waves. We use these data to create a compound risk index combining heat, COVID-19, density and social vulnerability. Our findings demonstrate that the compound risk of COVID-19 and heat are public health and equity challenges. Heat and COVID-19 exposure are influenced by natural, built, and social environmental factors, including access to mitigation infrastructure. Socio-demographic characteristics are significant indicators of COVID-19 and heat exposure and of where compound vulnerability exists. Using GIS mapping, we illustrate how COVID-19 risk geographies change across the three waves of the pandemic and the particular impact of vaccinations before the onset of the third wave. We, then, use our compound risk index to assess

heat interventions undertaken by the City, identify neighborhoods of both adequate and inadequate coverage and provide recommendations for future interventions.

B. Alahmad, A. Al-Hemoud, M. Al-Bouwarthan, H. Khraishah, M. Kamel, Q. Akrouf, D. H. Wegman, A. S. Bernstein and P. Koutrakis.

Extreme heat and work injuries in Kuwait's hot summers.

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE. 2023.

<https://doi.org/10.1136/oemed-2022-108697>

*Background*Hot, desert Gulf countries are host to millions of migrant workers doing outdoor jobs such as construction and hospitality. The Gulf countries apply a summertime ban on midday work to protect workers from extreme heat, although without clear evidence of effectiveness. We assessed the risk of occupational injuries associated with extreme hot temperatures during the summertime ban on midday work in Kuwait. *Methods*We collected daily occupational injuries in the summer months that are reported to the Ministry of Health's Occupational Health Department for 5 years from 2015 to 2019. We fitted generalised additive models with a quasi-Poisson distribution in a time series design. A 7-day moving average of daily temperature was modelled with penalised splines adjusted for relative humidity, time trend and day of the week. *Results*During the summertime ban, the daily average temperature was 39.4 degrees C (+/- 1.8 degrees C). There were 7.2, 7.6 and 9.4 reported injuries per day in the summer months of June, July and August, respectively. Compared with the 10th percentile of summer temperatures in Kuwait (37.0 degrees C), the average day with a temperature of 39.4 degrees C increased the relative risk of injury to 1.44 (95% CI 1.34 to 1.53). Similarly, temperatures of 40 degrees C and 41 degrees C were associated with relative risks of 1.48 (95% CI 1.39 to 1.59) and 1.44 (95% CI 1.27 to 1.63), respectively. At the 90th percentile (42 degrees C), the risks levelled off (relative risk 1.21; 95% CI 0.93 to 1.57). *Conclusion*We found substantial increases in the risk of occupational injury from extremely hot temperatures despite the ban on midday work policy in Kuwait. 'Calendar-based' regulations may be inadequate to provide occupational heat protections, especially for migrant workers.

Y. C. Zhu, Y. D. Mao, Y. L. Li, T. W. Tang, H. L. Jiang, S. C. Qiao, S. P. Lin, Z. M. Zheng, Z. S. Fang and X. H. Chen.

Field investigation of the heat stress in outdoor of healthcare workers wearing personal protective equipment in South China.

FRONTIERS IN PUBLIC HEALTH. 2023;11.

<https://doi.org/10.3389/fpubh.2023.1166056>

Since the advent of coronavirus disease 2019 (COVID-19), healthcare workers (HCWs) wearing personal protective equipment (PPE) has become a common phenomenon. COVID-19 outbreaks overlap with heat waves, and healthcare workers must unfortunately wear PPE during hot weather and experience excessive heat stress. Healthcare workers are at risk of developing heat-related health problems during hot periods in South China. The investigation of thermal response to heat stress among HCWs when they do not wear PPE and when they finish work wearing PPE, and the impact of PPE use on HCWs' physical health were conducted. The field survey were conducted in Guangzhou, including 11 districts. In this survey, HCWs were invited to answer a questionnaire about their heat perception in the thermal environment around them. Most HCWs experienced discomfort in their back, head, face, etc., and nearly 80% of HCWs experienced "profuse sweating." Up to 96.81% of HCWs felt "hot" or "very hot."

The air temperature had a significant impact on thermal comfort. Healthcare workers' whole thermal sensation and local thermal sensation were increased significantly by wearing PPE and their thermal sensation vote (TSV) tended towards "very hot." The adaptive ability of the healthcare workers would decrease while wearing PPE. In addition, the acceptable range of the air temperature (T-a) were determined in this investigation.

A. Kim and G. Yoo.

Field-based Heatwave Risk Assessment of Outdoor Workers Measured by Wearable Sensors.

ASIA-PACIFIC JOURNAL OF ATMOSPHERIC SCIENCES. 2023.

<https://doi.org/10.1007/s13143-023-00326-4>

Increasing heatwave frequency due to climate change threatens outdoor workers' health. We aimed to assess the on-site heat strain level of outdoor workers using wearable sensors and identify the factors for consideration in developing individual-based heat adaptation strategies. Seven road construction workers were recruited and asked to wear necklace-form temperature loggers and smartwatches monitoring heart rate (HR). The questionnaire was delivered daily to ask about their psychological comfort level during work. Workers were exposed to up to 5.4 degrees C higher temperature than the official air temperature, indicating that the national heatwave alarm does not reflect on-site heat conditions. Based on the measured HR data, heat strain levels were defined. When HR exceeded the level of "180-age," we assumed extreme heat strain occurred, which requires immediate cessation of work. When HR exceeded 40% of the individual heart rate reserve (the difference between the maximum and resting HR), we assumed high heat strain occurred, indicating a stressed condition. High heat strain occurred in all workers on 9 of the 13 monitored days, whereas the official heatwave alarms were issued only on four dates. Additionally, three workers experienced extreme heat strain on two dates. The main factor for workers experiencing extreme heat strain was age. Comparing the heat strain levels from HR with the survey results, we found that the older workers considered their condition comfortable even under extreme and high heat strain. Thus, an individual sensor-based early-warning system is needed to prevent heat strain not perceived by outdoor workers. The findings emphasize the need for a personalized adaptation strategy for heatwaves and will be a baseline for developing a new work manual that mainstreams climate change impacts.

EPI, matériaux protecteurs/refroidissants

W. Chou, H. M. Lin, G. B. Chen, F. H. Wu and C. Y. Chen.

A Study on the Fire-Retardant and Sound-Proofing Properties of Stainless Steel EAF Oxidizing Slag Applied to the Cement Panel.

MATERIALS. 2023;16(8).

<https://doi.org/10.3390/ma16083103>

Because of incomplete recycling resource management and technology development, inorganic sludge and slag has been misused in Taiwan. The recycling of inorganic sludge and slag is a pressing crisis. Resource materials with a sustainable use value are misplaced and have a significant impact on society and the environment, which greatly reduces industrial competitiveness. To solve the dilemma of EAF oxidizing slag recycled from the steel-making process, it is important to find solutions to improve the stability of EAF oxidizing slags based on the innovative thinking of the circular economy. We can improve the value of recycling resources and solve the contradiction between economic development and environmental impact. The project team intends to investigate the development and application of reclaiming EAF oxidizing slags blended with fire-retardant materials, which will integrate R&D work from four different aspects. First, a verification mechanism is carried out to establish stainless steel furnace materials. Suppliers must be assisted in conducting quality management for EAF oxidizing slags to ensure the quality of the materials provided. Next, high-value building materials must be developed using slag stabilization technology, and fire-retardant tests must be conducted on the recycled building materials. A comprehensive evaluation and verification of the recycled building materials must be undertaken, and high-value green building materials must be produced with fire-retardant and sound-proofing characteristics. Integration with national standards and regulations can drive the market integration of high-value building materials and the industrial chain. On the other hand, the applicability of existing regulations to facilitate the legal use of EAF oxidizing slags will be explored.

Subham, R. Rathour, A. Das and R. Alagirusamy.

Development of thermal liner for extreme heat protective clothing using aerogel technology.

JOURNAL OF THE TEXTILE INSTITUTE. 2023.

<https://doi.org/10.1080/00405000.2023.2201913>

In this research, an attempt was made to develop and explore the thermal protective performance of the thermal liner and the effect of various preparation parameters of aerogel technology on it. Efforts have also been made to explore the scope of nanotechnology in finding the solution to problems coming in the way of high thermal stability and insulation of the thermal liner. Silica aerogel is a colloidal suspension of silica-based oxides in the air. Hence, it is a highly insulating material and shows one of the lowest densities for a similar performance. Here we took an approach to deploy silica aerogel composite as a thermal liner layer in order to ensure the aforesaid functionalities. To realize the objective, we tried to find the suitable fibre as well as suitable fabric structure for developing an aerogel on it. Further, we studied the effect of processing parameters such as ageing time, the effect of base catalyst and silylation time during aerogel synthesis on the protective performance of the developed thermal liner. Electrospun Nomex (R) fibre-aerogel composite and nomex (R) fibre-aerogel composite was also made, and it was compared to the thermal liner made of Nomex (R) IIIA nonwoven to find out how it worked. Aerogel treated sample with ammonium fluoride as catalyst performed best compared to sample with ammonium hydroxide as a base catalyst. An increase in ageing and silylation time led

to significant increase in the thermal protective performance of the developed aerogel-Nomex (R) composite due to a better aerogel formation inside the composite.

Maladies liées à la chaleur

W. S. Journeay, J. J. McCormick, K. E. King, S. R. Notley, N. Goulet, N. Fujii, T. Amano and G. P. Kenny.

Impacts of age, diabetes, and hypertension on serum endothelial monocyte-activating polypeptide-II after prolonged work in the heat.

AMERICAN JOURNAL OF INDUSTRIAL MEDICINE. 2023.

<https://doi.org/10.1002/ajim.23477>

Background With rising temperature extremes, older workers are becoming increasingly vulnerable to heat-related injuries because of age- and disease-associated decrements in thermoregulatory function. Endothelial monocyte-activating polypeptide-II (EMAP-II) is a proinflammatory cytokine that has not yet been well-characterized during heat stress, and which may mediate the inflammatory response to high levels of physiological strain. *Methods* We evaluated serum EMAP-II concentrations before and after 180 min of moderate-intensity work (200 W/m²) in temperate (wet-bulb globe temperature [WBGT] 16 degrees C) and hot (WBGT 32 degrees C) environments in heat-unacclimatized, healthy young (n = 13; mean [SD]; 22 [3] years) and older men (n = 12; 59 [4] years), and unacclimatized older men with hypertension (HTN) (n = 10; 60 [4] years) or type 2 diabetes (T2D) (n = 9; 60 [5] years). Core temperature and heart rate were measured continuously. *Results* In the hot environment, work tolerance time was lower in older men with HTN and T2D compared to healthy older men (both p < 0.049). While core temperature and heart rate reserve increased significantly (p < 0.001), they did not differ across groups. End-exercise serum EMAP-II concentrations were higher in young men relative to their older counterparts due to higher baseline levels (both p ≤ 0.02). Elevations in serum EMAP-II concentrations were similar between healthy older men and older men with HTN, while serum EMAP-II concentrations did not change in older men with T2D following prolonged work in the heat. *Conclusion* Serum EMAP-II concentrations increased following prolonged moderate-intensity work in the heat and this response is influenced by age and the presence of HTN or T2D.

Z. E. Petropoulos, S. A. Keogh, E. Jarquin, D. Lopez-Pilarte, J. J. A. Velazquez, R. Garcia-Trabanino, M. R. A. Sanchez, R. Guevara, A. Gruener, D. R. Allen, J. H. Leibler, I. S. Delgado, M. D. McClean, D. J. Friedman, D. R. Brooks and M. K. Scammell.

Heat stress and heat strain among outdoor workers in El Salvador and Nicaragua.

JOURNAL OF EXPOSURE SCIENCE AND ENVIRONMENTAL EPIDEMIOLOGY. 2023.

<https://doi.org/10.1038/s41370-023-00537-x>

Background There is growing attention on occupational heat stress in Central America, as workers in this region are affected by a unique form of chronic kidney disease. Previous studies have examined wet bulb globe temperatures and estimated metabolic rates to assess heat stress, but there are limited data characterizing heat strain among these workers. *Objective* The aims were to characterize heat stress and heat strain and examine whether job task, break duration, hydration practices, and kidney function were associated with heat strain. *Methods* We used data from the MesoAmerican Nephropathy Occupational Study, a cohort of 569 outdoor workers in El Salvador and Nicaragua who underwent workplace exposure monitoring, including continuous measurement of core body temperature (T_c), heart rate (HR), physical activity, and wet bulb globe temperature (WBGT), over the course of three days in January 2018 - May 2018. Participants represented five industries: sugarcane, corn, plantain, brickmaking, and construction. *Results* Median WBGTs were relatively high (>27 degrees C) at most sites, particularly when work shifts spanned the afternoon hours (e.g., 29.2 degrees C among plantain

workers). Sugarcane workers, especially cane cutters in both countries and Nicaraguan agrichemical applicators, had the highest estimated metabolic rates (medians: 299-318 kcal/hr). Most workers spent little time on break (<10% of the shift), as determined by physical activity data. Overall, sugarcane workers-particularly those in Nicaragua-experienced the highest T-c and HR values. However, a few workers in other industries reached high T-c (>39 degrees C) as well. Impaired kidney function (estimated glomerular filtration rate <90 mL/min/1.73 m²) was associated with higher T-c and HR values, even after adjustment. **Significance** This is the largest study to-date examining heat stress and strain among outdoor workers in Central America. Workers at sugar companies regularly experienced T-c > 38 degrees C (76.9% of monitored person-days at Nicaraguan companies; 46.5% at Salvadoran companies). Workers with impaired kidney function had higher measures of T-c and HR. **Impact statement** This study examined levels of occupational heat stress and heat strain experienced among outdoor workers in five industries in El Salvador and Nicaragua. We characterized heat stress using wet bulb globe temperatures and estimated metabolic rate and heat strain using core body temperature and heart rate. Sugarcane workers, particularly cane cutters and Nicaraguan agrichemical applicators, performed more strenuous work and experienced greater levels of heat strain. Impaired kidney function was associated with higher heart rates and core body temperatures.

K. Wohlgemuth, Y. Sekiguchi and J. Mota.

Overexertion and heat stress in the fire service: a new conceptual framework.

AMERICAN JOURNAL OF INDUSTRIAL MEDICINE. 2023.

<https://doi.org/10.1002/ajim.23482>

From the year 2000, the United States Fire Administration (USFA) has been recording all line-of-duty deaths in the fire service. Stress or overexertion caused 1096 out of 2598 total line-of-duty deaths in the United States from 2000 to 2021. Those deaths due to stress or overexertion were further classified as myocardial infarction (90%), cerebrovascular accident (6.8%), other (2.6%), and heat exhaustion (0.6%). Environmental heat exposure is a concern in firefighting, as firefighters work in extreme conditions, such as high ambient temperatures, while wearing protective clothing. Heat stress is not only hazardous to the cardiovascular system, but may accentuate muscle fatigue and overexertion. In addition, overexertion itself is related to increased incidence of musculoskeletal injuries, usually to the lower extremities. Further, there is a strong physiological mechanistic link to suggest that the increased occupational heat exposure and thermoregulatory strain firefighters experience may be a stressor that increases the risk of injuries. This commentary hopes to show the need for further research on the effects of occupational exposures and physiological strain in the fire service.

Outils et capteurs de mesure

S. R. Goods, P. Maloney, J. Miller, D. Jennings, J. Fahey-Gilmour, P. Peeling and B. Galna.

Concurrent validity of the CORE wearable sensor with BodyCap temperature pill to assess core body temperature during an elite women's field hockey heat training camp.

EUROPEAN JOURNAL OF SPORT SCIENCE. 2023.

<https://doi.org/10.1080/17461391.2023.2193953>

Wearable temperature sensors offer the potential to overcome several limitations associated with current laboratory- and field-based methods for core temperature assessment; however, their ability to provide accurate data at elevated core temperatures (T_c) has been questioned. Therefore, this investigation aimed to determine the concurrent validity of a wearable temperature sensor (CORE) compared to a reference telemetric temperature pill (BodyCAP) during a team-sport heat training camp prior to the 2020 Olympic Games. Female field hockey players ($n = 19$) in the Australian national squad completed 4 sessions in hot conditions where their temperature was monitored via CORE and BodyCAP. Concurrent validity of the wearable CORE device was determined with reference to the ingested BodyCAP pill. Lin's Concordance Correlation Coefficients determined there was "poor" agreement between devices during all sessions. Mean bias demonstrated that CORE underestimated T_c in all sessions (-0.06 degrees C to -0.34 degrees C), with wide mean 95% confidence intervals (± 0.35 degrees C to ± 0.56 degrees C). Locally estimated scatterplot smoothing regression lines illustrated a non-linearity of error, with greater underestimation of T_c by the CORE device, as T_c increased. The two devices disagreed more than ± 0.3 degrees C for 41-60% of all data samples in each session. Our findings do not support the use of the CORE device as a valid alternative to telemetric temperature pills for T_c assessment, particularly during exercise in hot conditions where elevated T_c are expected. HIGHLIGHTS The CORE wearable sensor is not a valid alternative to telemetric temperature pills for T_c assessment, particularly during exercise in hot conditions where elevated T_c are expected. Compared to reference T_c data provided by a validated, ingestible telemetric temperature pill, the CORE device demonstrated "poor" agreement between devices during all sessions in this investigation. There was a non-linear bias which tended to underestimate T_c to a greater extent as T_c increased (but with wide confidence intervals), with 41-60% of all data exceeding a threshold error of ± 0.3 degrees C.

Actualités avril 2023

- **Travail par fortes chaleurs et périodes de canicule**

[The work must go on: No respite to workers even as temperature soars to 40 degrees Celsius in Kerala.](#) Newindianexpress.com

[Centre asks States, UTs to ensure prep for easing effects of heat wave on workers.](#) Uniindia.com

[Odisha heat wave: Working hours of labourers changed in state.](#) Newindianexpress.com

[Emploi : l'alerte du Conseil économique, social et environnemental sur l'impact des canicules sur la vie des travailleurs.](#) Francetvinfo.fr

[Climat et santé : "La canicule doit être considérée comme un motif d'arrêt de travail".](#) Lexpress.fr

[Comment le dérèglement climatique a déjà bouleversé le monde du travail.](#) Madeinperpignan.com

[Sécurité et bonnes conditions de travail pas toujours au rendez-vous sur certains chantiers.](#) Imazpress

Les Fonderies de Sougland fascinent les visiteurs. L'Union, 19 avril 2023

[« Plutôt que travailler plus, il faut travailler autrement à l'aune du dérèglement climatique ».](#) Liberation.fr

- **Maladies liées à la chaleur**

[Fire official: Murrysville volunteer suffers heat exhaustion while battling house fire.](#) Triblive.com

- **EPI, matériaux protecteurs/refroidissants**

[Highly integrated bionic prostheses resolve the thermal asymmetry between residual amputated and contralateral limbs.](#) Nature.com

[Non-invasive mass and temperature quantifications with spectral CT.](#) Nature.com

[United States: Washington's Department Of Labor And Industries Proposes Changes To Permanent Heat Illness Prevention Rules For Outdoor Workers.](#) Mondaq.com