Monitoring housing conditions for migrant and temporary foreign agricultural workers (MTFAWs) on southern Ontario farms, Summer 2024: Implications for worker heat stress

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Summary

Heat stress is a growing concern among agricultural workers and stakeholders. OHCOW assisted migrant and temporary foreign agricultural workers (MTFAWs) in monitoring temperature and other relevant factors in their housing. Heat stress conditions were documented, particularly during heat waves. These conditions impacted workers' sleep quality and their ability to recover from heat stress experienced during the workday. More attention needs to be paid to ensure all worker housing has adequate ventilation and temperature control.

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Background

OHCOW has worked with migrant and temporary foreign agricultural workers (MTFAWs) for over two decades, listening to their work and health concerns, conducting workshops and providing resources in multiple languages. Over a similar period, OHCOW has supported Ontario workplace stakeholders to better assess and respond to worker heat exposure, recognizing the impacts of heat stress on both worker health and work productivity (see *Appendix A***.** Heat stress impacts on worker health and productivity) and the more frequent heat waves occurring with climate change. Environment Canada uses Humidex to express how the combined effects of warm temperatures and humidity are perceived. OHCOW's collaborative work has informed various iterations of a modified Humidex Based Heat Response Plan. MTFAWs have raised heat concerns for both outside and greenhouse work. OHCOW has responded with prevention based, educational materials, posters and workshops in key worker languages emphasizing shade, rest breaks, hydration, and other heat stress mitigation options, as well as what to do in a heat–related illness emergency.

MTFAWs have also raised concerns about heat stress in employer provided housing. Although not necessarily considered part of the workplace by the Ontario Ministry of Labour, Immigration, Training and Skills Development (MLITSD), employer-provided housing is within scope of the Workplace Safety and Insurance Board (WSIB). In 2023, several workers in the Niagara region contacted OHCOW outreach workers regarding extremely hot housing, poor ventilation and poor air quality – reported to their employer without improvement. Conditions reduced their effective sleep to only a few hours during the hottest periods, providing inadequate recovery and rest for their next workday.

To better understand these conditions OHCOW provided one MTFAW with an *Aranet 4 Home* temperature/relative humidity and carbon dioxide monitor, explained its use, and instructed the worker on how to share the data with their regional OHCOW outreach worker. OHCOW staff provided assurance that recorded conditions would not be reported to any regulatory parties or their employer unless it was the worker's decision to do so (see *Appendix C***.** Acknowledging the vulnerability of MTFAWs). The worker took a photograph of the *Aranet* temperature/humidity monitor display on five occasions and shared the photographs with the OHCOW outreach worker. All five recorded temperatures were higher than outdoor weather data for the same period. Further, all were above 26°C, a level the Chief Coroner of British Columbia identified as a serious concern (*Extreme Heat and Human Mortality: A Review of Heat-Related Deaths in B.C. in Summer 2021, June 7, 2022)*.

> *"High indoor temperature was the primary cause of injury and death during the extreme heat event. During this time, hot air became trapped indoors and continued to rise over time. Although outdoor temperatures decreased overnight, residences did not cool off, exposing people to harmful high temperatures for extended periods of time. The BC Centre for Disease Control (BCCDC) identified that people were most in danger when indoor temperatures remained above 26 degrees throughout the heat event (page 22.)*

Based on expressed concerns from additional MTFAWs' and this collaborative measurement experience, the OHCOW Heat Stress project team decided to expand data collection to more worker housing in the Niagara and Simcoe Ontario regions during the summer of 2024.

Objectives

This project was a formal collaboration among MTFAWS and OHCOW, including outreach workers, an occupational hygienist, an occupational physician, and project manager. We sought to achieve multiple objectives, included the following:

1. Utilize accepted assessment tools for characterizing heat stress exposures, both during work (i.e. using public weather data) and during the heat stress recovery period (i.e., inside worker housing after work).

2. Compare the feasibility and accuracy of different small, portable thermo-hygrometers for measuring indoor and outdoor conditions.

3. Develop an ethical recruitment approach as well as a worker-engaged training strategy to empower and support workers in monitoring their housing conditions. Ensure the approach is rigorous, feasible, and transparent for MTFAWs, while making efforts to ensure confidentiality for participating workers and reduce risk of employer reprisal. Establish a worker-friendly, systematic approach to data collection, transmittal, and consolidation.

4. Assess the outdoor daily heat exposure of MTFAWs, using the American Conference of Governmental Industrial Hygienists (ACGIH) Heat Stress/Strain Threshold Limit Values (TLVs).

5. Assess the heat exposure conditions that MTFAWs face in their housing after work and whether some housing characteristics might mitigate heat stress, given these conditions may impact workers' ability to recover from any heat stress experienced during the day (as assumed by the TLV).

6. Report key findings to MTFAWs to raise awareness of the potential harms of heat stress, the strategies to prevent heat stress, and the importance of access to the conditions and resources to support recovery from heat stress.

7. Report findings to additional parties (farm owners, academics, regulatory agencies, medical professionals, etc.) to inform future policy and program development related to improved housing quality for MTFAWs.

Methods

a. Region and ambient weather data retrieval

The daytime occupational exposure to heat stress was assessed using data from the nearest Meteorological Service of Canada (Environment and Climate Change Canada) weather station. Since only a few weather stations have hourly solar radiation measurements, the Vineland weather station data was used to provide the solar radiation data for all other weather stations. Although one site of worker housing was closer to another weather station with solar radiation information (the Guelph weather station), Vineland is closer in latitude, making it a more important consideration for generalizability of its weather data.

b. Monitoring instruments testing

OHCOWs occupational hygienist tested a range of electronic thermo-hygrometers, as displayed in *Appendix B.* Comparing electronic Thermal Hygrometers The *Aranet4 Home*, which measures temperature (temp), relative humidity (RH) and carbon dioxide (CO_2) was initially selected. It displays these values, providing immediate information to the volunteer MTFAW. Another accurate recording instrument, the *Switchbot*, does not display such information and is smaller, creating an advantage if the MTFAW wanted their monitoring to be more discrete. Therefore, we trialed both thermo-hygrometers (details in *Appendix B.* Comparing electronic Thermal Hygrometers).

c. Outreach worker training and worker recruitment

OHCOW's occupational hygienist conducted a training session for two outreach workers explaining operation of the sensor equipment and how to download the data. Guidelines for worker recruitment including education, assurance of confidentiality, and use of the collected data were developed in the context of MTFAW vulnerability (see *Appendix C.* Acknowledging the vulnerability of MTFAWs). A brief questionnaire was developed to describe the worker housing, along with floor plan diagrams if possible, and key heat mitigation characteristics, as noted by Laouadi and colleagues (2020). In this pilot work, outreach workers recruited interested workers, without regard to the potential quality of their housing.

d. Data collection, retrieval, initial processing

Eleven volunteer MTFAWs placed *Aranet4 Home* sensors in their worker housing beginning at various times, starting in late June through to early August 2024. Complete information was not obtained on all housing characteristics, particularly diagrams, but we were able to obtain pictures of worker housing using geographical locations (e.g. address or coordinates) and Google Maps. Workers monitored for various periods of time from June 28 to the end of October 2024, without questions from their employers. Due to challenges in MTFAWs and OHCOW outreach workers' availability, not all data downloads took place within the 15-day window of the *Aranet4* sensors' active memory capacity, so some gaps occurred in worker housing monitoring data collected. Outreach workers transmitted all downloaded data to OHCOWs occupational hygienist for entry into spreadsheets, data visualization and analysis.

e. *Data analysis for heat stress*

i. ***Outdoor work conditions*** *- American Conference of Governmental and Industrial Hygienists (ACGIH) Heat Stress/Strain Threshold Limit Value (TLV)*

For occupational heat stress exposure and prevention of heat strain, the American Conference of Governmental and Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) is commonly considered the "gold standard" among occupational hygienists. The ACGIH Heat Stress/Strain TLV assesses heat stress exposure by combining the wet bulb, the dry bulb and globe temperatures according to a formula (see *Appendix D.* Assessing heat stress during work) to provide what is called a wet-bulb globe temperature (WBGT). The effective WBGT ($WBGT_{eff}$) is the measured WBGT adjusted based on a categorization of multiple important factors that can impact heat stress, including the work metabolic rate, clothing adjustment values, hourly work/rest cycles and acclimatization. Acclimatization is the process by which our bodies adapt to changes in our environments, and in this case, to be less affected by heat stress.

Since the weather data does not provide WBGT measurements, these were derived from the hourly temperature, relative humidity, wind velocity (from local weather stations) and solar radiation data from the Vineland weather station. These hourly data were converted to outdoor WBGT measurement using the UTCIWBGT Calculator, an Excel spreadsheet that can calculate outdoor hourly WBGT values. The ACGIH Heat Stress/Strain TLV assumes heat stress exposure occurs for 8-hour workdays, 5 days per week, with adequate recovery time after hours. However, this is not the common situation for MTFAWs.

Parsons (*2014, Chapter 13*) dismissed the sometimes-voiced opinion that workers from hot climates are already acclimatized i.e. acclimatization based on country of origin. The ACGIH acclimatization criterion states that *"Acclimatization declines when activity under heat stress conditions is discontinued. A noticeable loss occurs after 4 days and may be completely lost in 3 weeks. A person may not be fully acclimatized to a sudden or episodic higher level of heat stress."* (*ACGIH® © 2022 11DOC-658-NPA Heat Stress and Strain TLV – page 4*), Therefore, by the ACGIH criteria, even if a worker has arrived to Southern Ontario in an acclimatized state, that worker will likely "completely" lose their acclimatization after "3 weeks" if they aren't exposed to heat stress conditions.

ii. ***Indoor worker housing conditions*** *- Standard effective temperature (SET)*

Another heat strain index is called Standardized Effective Temperature (SET), primarily used when evaluating heat strain in buildings, including residences (see *Appendix E.* Calculating and choosing SET values for housing SET is like the WBGT in that it accounts for: clothing, relative humidity, metabolic rates, air movement, and radiant heat. The difference is that rather than adjusting after the measurement (as for the WBGT), these adjustments are incorporated into the final SET calculation. The conditions measured are adjusted in relation to a standard reference set of conditions (50% RH, <0.15 m/s air velocity, 1.2 met metabolic rate, and 0.9 clothing rating and no radiant heat). *Table 2 in housing provides* a range of SET values and implications. Across all the various methods and schemes, for northern temperate climates the criteria seem to circle around a SET = 26°C as the threshold for heat problems, and a SET = 30°C for unacceptable.

Results

a. Outdoor heat exposure

We plotted graphs showing the derived outdoor WBGT values for the time period from May 18, 2024, to the end of September (after the last day when the derived outdoor WBGT exceeded 24°C WBGT). Results from ***Figure 1.*** show the days in which MTFAWs would have been working in conditions requiring extra measures to reduce their heat stress (see red bands) to mitigate impacts on worker health and productivity (*Flouris et al, 2018* –see extract in *Appendix A.*) Of note, there were 3-days of significant heat stress exposure June 18-20, 2024, when a “heat dome” moved over Southern Ontario from the United States. Deployment of the temperature and humidity sensors in worker housing did not begin until the end of June and thus we missed heat exposure during this first and most intense heat wave of the 2024 season.

To ascertain whether outdoor workers can be considered acclimatized, the ACGIH Heat Stress/Strain TLV provides a guideline of heat stress exposure for at least 2 continuous hours in the last 5 or 7 days. Clearly from ***Figure 1.*** and ***Figure 2.*** outdoor workers experiencing direct sunlight based on the Lincoln (Vineland) weather station did not experience sufficient heat stress exposure to be considered acclimatized (getting used to heat or able to withstand heat stress) by the ACGIH criteria. However, note that the ACGIH TLV assumes adequate recovery time and a work week of five 8-hour days’ exposure. Some of the workers we engaged told us they worked 7 days/week and more than 8 hours per day. Without adequate recovery time, they cannot acclimatize to be able to withstand heat stress.

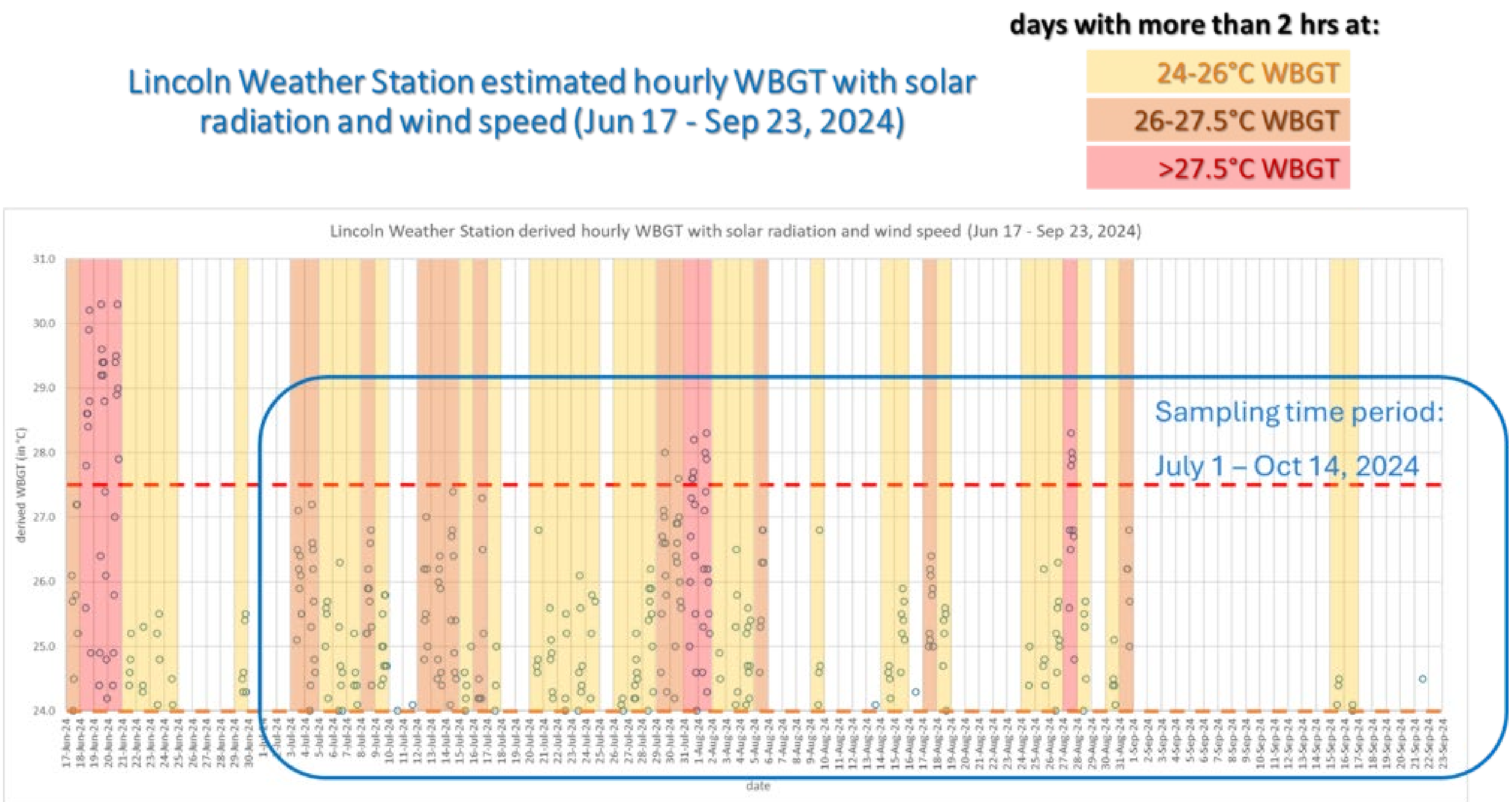

Figure 1. *Estimated outdoor hourly WBGT with solar radiation and windspeed*

Red dotted line indicates WBGT of 27.5^{0}C

There were two other occasions when the derived outdoor WBGT levels exceeded the 27.5°C WBGT criterion for "ACGIH defined acclimatization" for "Heavy" work at a 50-75% work/rest regimen (the red dashed line in ***Figure 1***.): on July 31 – August 1, and August 27, 2024. ***Figure 2.*** divides the WBGT temperature areas where in which workers would need to be acclimatized to work (ACGIH 27.5°C WBGT) – three over the summer and two during the sampling period.

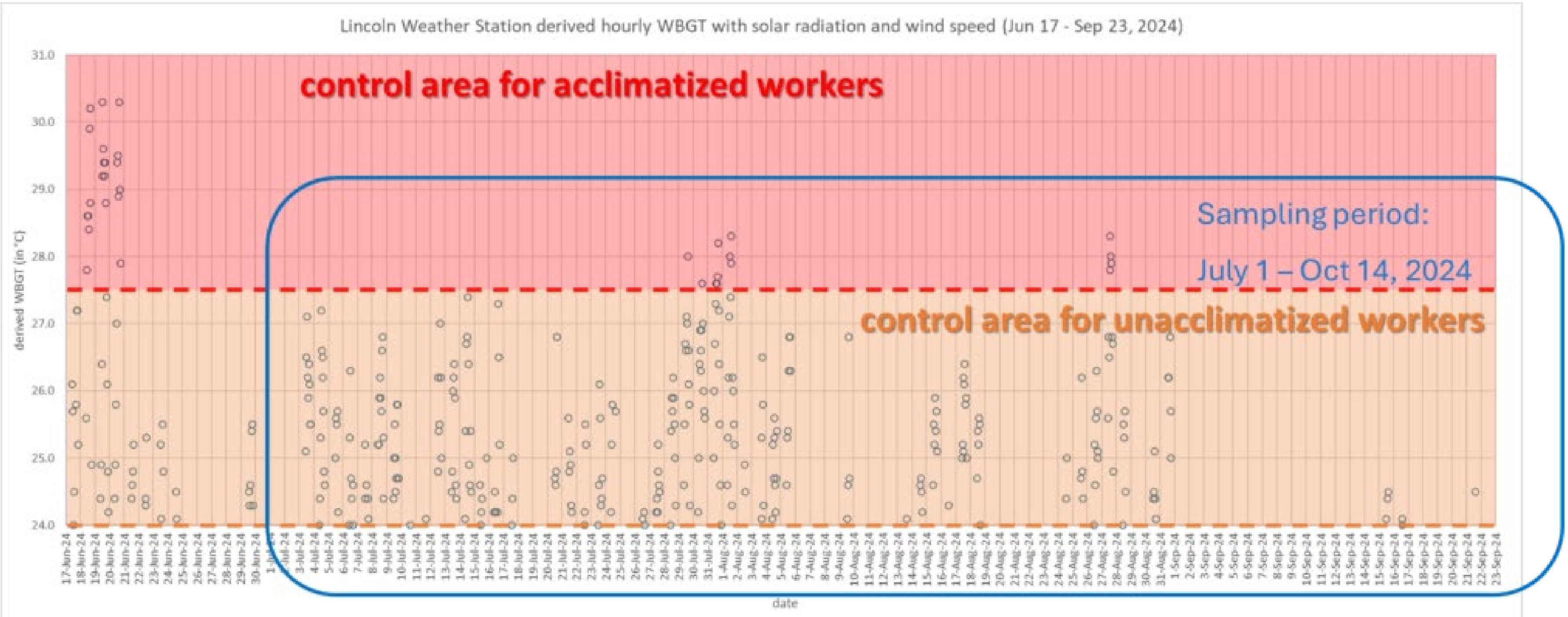

Figure 2. *Lincoln Weather Station derived hourly WBGT with solar radiation and wind speed included (May 18 - Sep 30, 2024), banded for un-acclimatized and acclimatized workers.*

b. Housing heat exposure

Among the eleven worker housing sites which MTFAWs monitored, four were houses, three trailers, two converted storage sheds and two purpose built bunkhouses for housing MTFAWs. We use the term bunkhouses, abbreviated as BH, for all these types of housing. Four bunkhouses were in the shade and three had some form of curtains or blinds (though mostly inside, limiting their effectiveness in reducing heat accumulation). Nine had the possibility of cross drafts when windows (ranged from one to sixteen) were open and screens intact, but the latter were often frayed, letting in insects. Only three had some form of air conditioning (two window mounted units in kitchens, one split wall unit in a bedroom). *Aranet* readings were available for all bunkhouses (range N =168 to 2231 hourly samples), with *SwitchBot* readings (N=395 to 1281 hourly samples, indicated with purple bars in ***Figure 3.***) available on four bunkhouses. ***Figure 3.*** displays the days in which sampling data were available for each bunkhouse, overlaid on the day's outdoor WBGT classification. Despite the missing data, we did capture data from at least some worker housing for many of the higher WBGT days, and each of the more extreme days (except in June as noted above). *SwitchBot* data collection time periods are shown as purple bars.

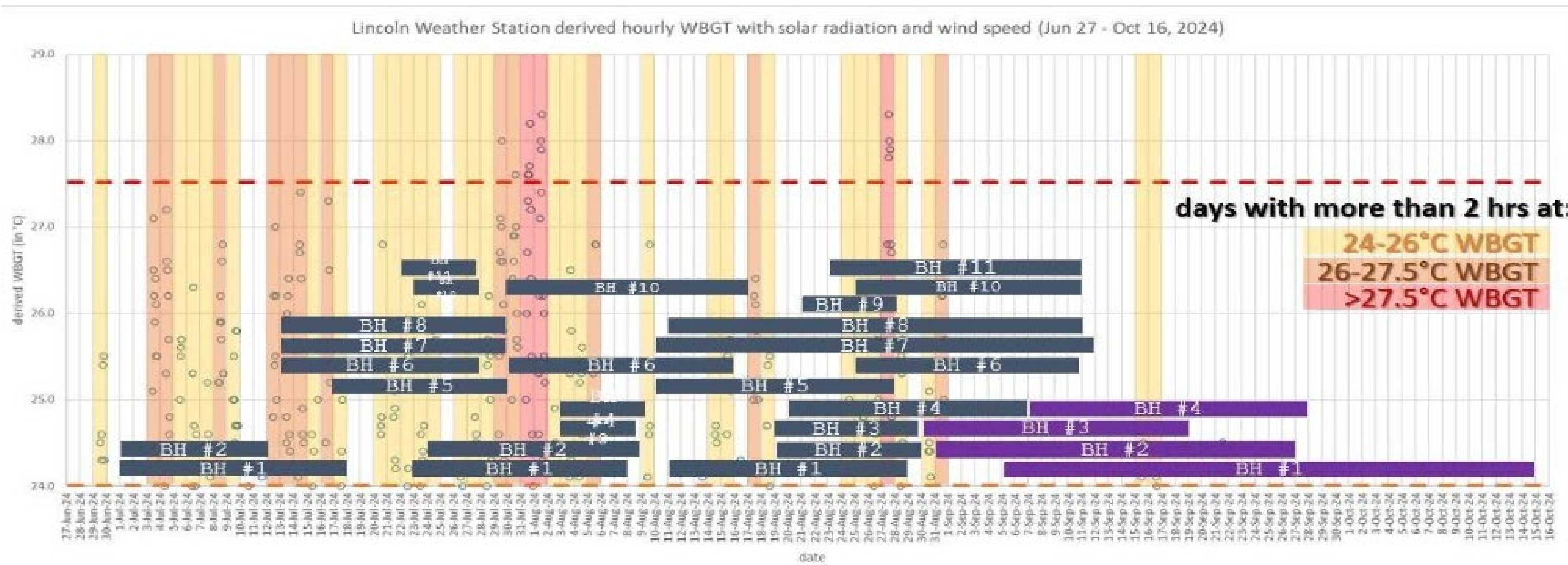

Figure 3. *Bunkhouse sampling periods*

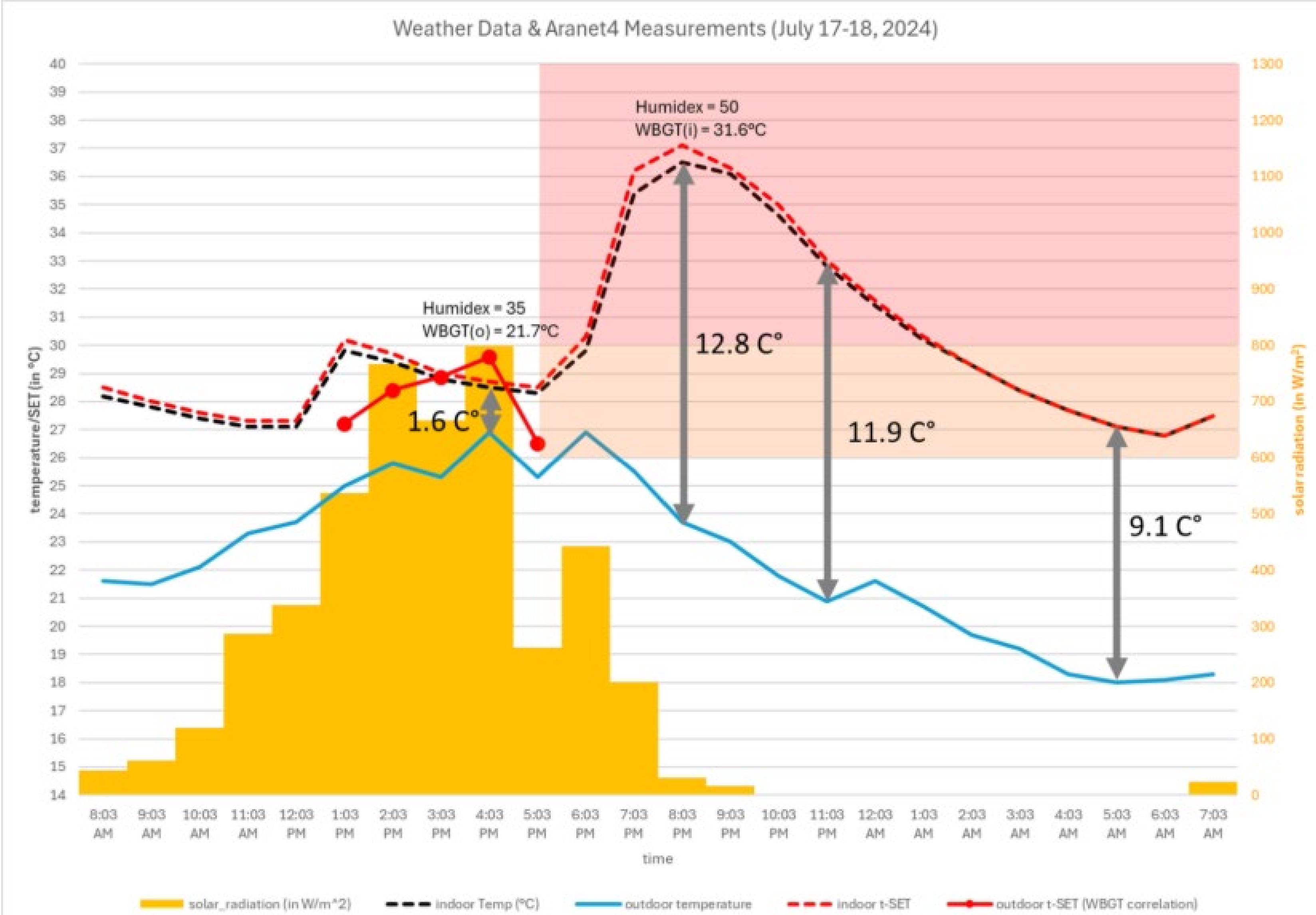

Figure 4. *Example of sampling measures for a single bunkhouse over 24 hours during a moderately hot period*

Several key points are demonstrated in ***Figure 4.*** from one bunkhouse over 24 hours:

i. Outdoor Humidex (red continuous line) rises to a high value of 35 (outdoor WBGT = 21.7°C) in the late afternoon during MTFAWs workday, reflecting solar radiation (yellow fill histogram);

ii. Indoor SET temperature (red dashed line) soars highest in the early evening (SET = 37.1°C; Humidex = 50; indoor WBGT = 31.6°C), when MTFAWs return to cook, shower etc. after work, and continues through the middle of the night, as MTFAWs have described i.e. that they can sometimes only fall asleep around 2 am; and

iii. The indoor to outdoor difference (arrows between the blue outdoor temperature line and the black dashed indoor temperature line) is also most dramatic in the evening (12.8^{0} C) but continues well into the early morning demonstrating substantial heat retention in workers' housing.

The indoor-outdoor temperature difference across multiple days is apparent in a non-air-conditioned BH - ***Figure 5.*** Although daily variation is apparent, the percentage of time (89 %) the SET levels are above the SET sleep criterion of 26^{0} C is substantial, indicating inadequate indoor conditions during much of workers' sleeping time.

Looking across all the worker housing data (***Table 1.***), some reduction in the percentage of time above the SET levels with more heat mitigation characteristics of the housing is apparent during the warm (yellow) period (i.e. from 82.5% to 55.0% above a SET of 26^{0} C and from 31.0% to 18.3% above a SET of 30^{0} C). However, such reductions were not apparent during the hottest (red) periods of the summer, indicating the inadequacy of current heat mitigation in worker housing, including the following: not enough shade, inappropriate or inadequate blinds, not enough functioning windows with screens for natural night cross-draft ventilation, and/or inadequately sized or maintained air conditioning systems for the space and occupancy in the worker housing.

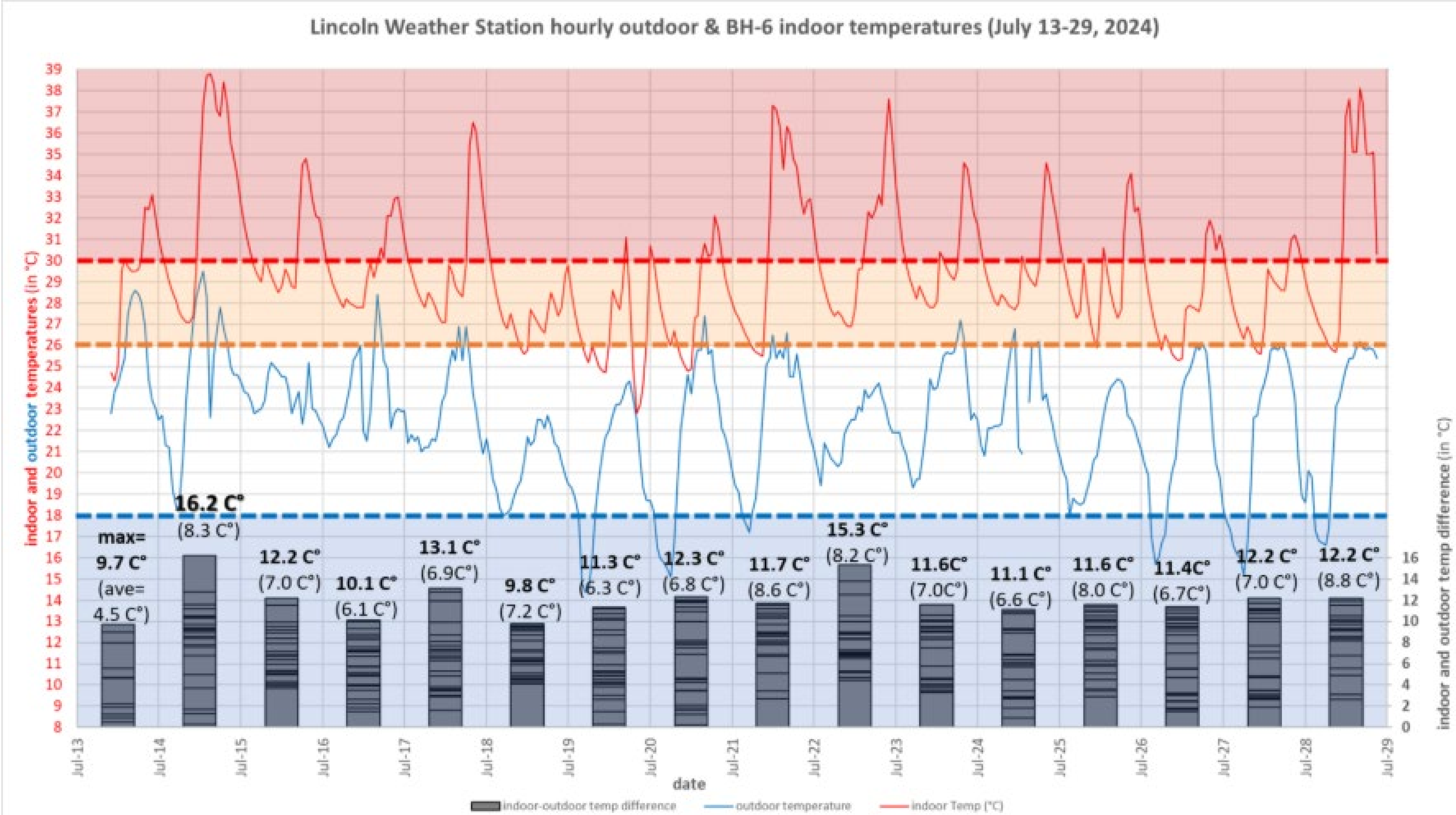

Figure 5. *Bunkhouse 6 indoor temperatures compared to hourly outdoor Lincoln Weather Station temperatures (13-29 July 2024)*

	July 13-29
% above SET=26°C:	89.0%
% above SET=30°C:	42.4%
ave indoor SET 5-10 pm	31.7°C
ave indoor SET 11 pm-7 am	28.8°C

Table 1. *SET (standard effective temperature) in bunkhouses (BHs) during distinct periods, by presence of mitigative elements*

Periods and BHs sampled			**BH Heat Mitigative Elements**			**SET (indoors) - average for BHs in row**		**Evening & night Indoor - outdoor temperature difference - average for BHs in row**		
Dates range^	**Range of outdoor WBGT**	**BHs with data for period**	**Sunshade, curtains-blinds & x-draft score***	**Air condition-ing**	**BHs with combined elements**	% time > 26°C	% time > 30°C	min (°C)	avg (°C)	max (°C)
23-26 July	24-26° C	1,2,5,6,7,8,10,11	0 or 1	no	1,6	82.5%	31.0%	6.0	7.7	9.1
			2 or 3	no	5,7,8,10	62.5%	10.8%	3.0	5.1	7.1
			2 or 3	yes	2,11	55.0%	18.3%	4.1	6.6	10.5
13-16 July	26-27.5° C	1,6,7,8	0 or 1	no	1,6	91.7%	41.7%	4.1	6.3	8.2
			2	no	7,8	93.4%	6.7%	2.1	4.5	6.7
31 July - Aug 3	>27.5° C	1,2,6	0 or 1	no	1,6	100.0%	65.9%	4.0	5.8	8.0
			2	yes	2	100.0%	46.7%	5.4	7.0	8.0
27-29 Aug	>27.5° C	2,3,4,6,7,8,11	0 or 1	no	3,4,6	67.4%	16.7%	1.3	4.9	7.8
			2 or 3	no	5,7,8	91.7%	16.7%	2.0	8.3	10.0
			2 or 3	yes	2,11	63.4%	20.0%	3.2	6.0	8.8

^If sufficient data from BHs, added one day to outside temperature periods to cover lag in indoor temperatures

*Score was the sum of elements listed

Discussion

OHCOWs collaborative work with MTFAWs in the summer of 2024 demonstrated the potential for a double burden of heat stress (i.e. during the workday using the ACGIH TLV, and during the evening-night, using recommended SET levels). Heat stress can cause serious short-term and long-term effects as indicated in OHCOW's Heat Stress Toolkit. Protective measures must be put in place to support MTFAW health, including limiting exposure to high temperatures and humidity, and ensuring these workers have access to the conditions and resources to support recovery when they are exposed.

Currently, this double burden is not addressed by either the work oriented ACGIH TLV or the building SET guidelines alone. Additional work is needed to better understand the implications of:

i. Prolonged work hours and seven-day work schedules experienced by many MTFAWs; and
ii. Potential lack of recovery time from work heat stress, when worker housing does not permit recovery nor rest; and
iii. Combination of i. and ii. upon acclimatization, if any, among MTFAWs.

Each of these needs to be considered by governments and stakeholders with a focus on daytime work or on housing, in a joint collaborative process that does not leave MTFAWs suffering this double burden.

Focusing on housing, MTFAWs facing heat stress have not received adequate improvements or responses from federal or municipal authorities. In 2023, when a worker asked OHCOW about options to report excessive temperatures compared to heat stress standards, reports were made to the Employment and Social Development Canada (ESDC) TFW Tip line and to Niagara Public Health. The ESDC Tip Line agent mentioned that they would not be providing a report number nor updates on their response or actions following our report. The Niagara Public Health office response included:

> *"…Unfortunately, there is no maximum temperature that is allowable and again no air conditioning units are required…." (email reply from Jason Wolf CPHI(C), Public Health Inspector – Team Lead, Niagara Public Health, July 25, 2023).*

This situation is different from other jurisdictions with clear guidelines, such as Oregon Occupational Safety and Health's (OSHA) 2022 rule addressing high ambient temperatures in labour housing. Hence, there is a need for clear action levels and supports for housing improvement which enable stakeholders and governments to better respond, as per a recent pan-Canadian effort. From the work reported here, an important step would be modification of the ESDC housing inspection report format in the Housing Interior section.

Either item 3 or 5 are pertinent below:

3. Is a permanent heating system that can maintain a temperature ranging between 20 to 23.5 degrees Celsius (68 to 75 degrees Fahrenheit) available within the housing?

A room temperature ranging between 20 to 23.5 degrees Celsius (68 to 75 degrees Fahrenheit) is the minimum standard. Portable space heaters cannot be used as the primary source of heating for any living space within the housing.

☐ Yes ☐ No ☐ Could not be verified during this inspection due to:

5. Is there adequate ventilation by either natural or artificial means in the housing?

To prevent poor air quality, adequate ventilation by either natural means (e.g. windows) or artificial means (e.g. ceiling fans) is required.

☐ Yes ☐ No ☐ Could not be verified during this inspection due to:

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At least one of them should include:

b. Is there a ventilation and/or cooling system that can maintain a temperature below 26 degrees Celsius (79 degrees Fahrenheit) in any living space within the housing?

☐ Yes ☐ No ☐ Could not be verified during this inspection due to: ____________________

With such guidance, provincial and municipal authorities, their staff and contractors would have a clear guideline to implement (including via inspections) during the hottest parts of the summer. OHCOW will continue to provide assistance to MTFAWs monitoring their housing and work conditions and providing assistance in addressing the double burden of heat stress.

References

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Appendices

Appendix A. Heat stress impacts on worker health and productivity
Appendix B. Comparing electronic Thermal Hygrometers
Appendix C. Acknowledging the vulnerability of MTFAWs
Appendix D. Assessing heat stress during work
Appendix E. Calculating and choosing SET values for housing

Appendix A. Heat stress impacts on worker health and productivity

This extract (page 527) from a major global review by Flouris and colleagues emphasizes the substantial impacts of heat stress:

> "Most of the 111 studies included in this systematic review suggest that working in hot conditions (WGBT >22°C for very intense work; WBGT >25°C for most occupations) increases the likelihood of experiencing occupational heat strain, with significant detrimental effects on health and productivity. We attempted to quantify these effects by extracting data from 64 of these studies for use in six meta-analyses. Our results showed that individuals working in heat stress conditions were four times more likely to experience occupational heat strain during or at the end of a work shift compared with individuals working in thermoneutral conditions. Indeed, working a shift in thermoneutral conditions did not lead to physiological or clinical effects on core temperature, which, on average, remained at 36·9°C (SD 0·3). However, individuals who worked a single shift in heat stress conditions showed average core temperature values of 37·6°C (SD 0·4), while 35% of them experienced occupational heat strain.
>
> This occupational heat strain is also associated with dehydration; our analyses show that people who worked a single shift in heat stress conditions had an increase of 14·5% in urine specific gravity compared with those who worked a shift in thermoneutral conditions. Given the well-established links between hydration and kidney function, we were not surprised to find that 15% of individuals who typically or frequently (minimum of 6 h per day, 5 days per week, for 2 months of the year for most occupations) worked in heat stress conditions had kidney disease or acute kidney injury.
>
> Finally, in our analyses, 30% of individuals working in heat stress conditions had losses in productivity. *These losses increased by 2·6% for every degree increase beyond 24°C WBGT*."

Source: Flouris AD, Dinas PC, Ioannou LG, *et al*. (2018). Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. *Lancet Planetary Health* 2 (12): E521-E531 https://doi.org/10.1016/S2542-5196(18)30237-7 Open access.

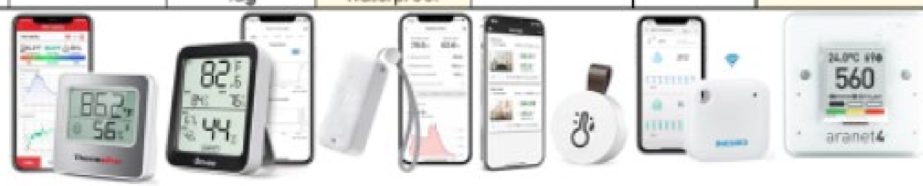
Appendix B. Comparing electronic Thermal Hygrometers

The OHCOW occupational hygienist undertook a comparison of a wide range of portable, electronic monitoring devices, some of which also include carbon dioxide measurements as an indicator of indoor air quality and indirectly adequacy of ventilation for different numbers of workers within a space i.e. occupancy density.

In general, most sensors were close on temperature and relative humidity values:

thermo-hygrometers with data download apps:

Thermo-Hygometers with apps:	ThermoPro	Govee	SwitchBot	SensorBlue	InkBird	Aranet CO_2
download	from account	from account	direct but via text	direct	direct	direct
time interval	1-min	1-min	1-min	10-min	2-min	1-min
export time length	at least 1 month	at least 1 month	68 days	14-days	14-days	3-months (3.5 days)
specified accuracy (temperature in ±°C)	±0.5°C	±0.3°C	± 0.2°C	±0.5°C	±0.3-0.5°C	±0.3°C
specified accuracy (relative humidity in ±%)	±2%RH	±3%RH	±1.8%RH	±3%RH	±3-4.5%RH	±3%RH
temp average error (10-min sample/averages)	0.0	0.1	-0.1	0.1	0.5	ref
% time within <0.5°C difference from Aranet	98.6%	88.8%	99.3%	96.8%	66.0%	ref
% time >1.0°C difference from Aranet	0.0%	2.7%	0.3%	2.4%	1.6%	ref
comparisons (n=)	1359	1301	1074	1359	1172	1359
RH average error (10-min sample/averages)	0.3	0.5	0.6	2.5	1.3	ref
% time within <3% difference from Aranet	88.0%	93.3%	99.9%	77.3%	91.7%	ref
% time >7.5% difference from Aranet	0.0%	0.0%	0.0%	0.0%	0.0%	ref
notes	display	display; data has an increasing time lag	no display; indoor/outdoor dustproof/ waterproof	no display	no display	display



Among the thermos-hygrometer which have apps that allow the downloading of data so that outreach workers could download data on periodic visits to worker housing, some performed better and more accurately than others, with the *SwitchBots* being the closest to the *Aranet 4* (which we had previously validated and considered our “gold standard”):

We had started with the *Aranet* thermo-hygrometers and later added *SwitchBot* monitors. Furthermore, when the *Aranets* record data every 5 minutes, the memory capacity of the sensor is only 15 days (after which older data is not saved), requiring more complicated coordination and regular biweekly visits. At the end of the sampling season, we realized that the 5-minute sampling frequency could be extended to 10-minute grab samples thus extending the active memory to one month. During the season we also evaluated several other inexpensive (<$30) thermo-hygrometers. Of the sensors evaluated, the *SwitchBot IP65 Indoor/Outdoor Thermo-Hygrometer* was able to store 1-minute measurements in active memory for 2 months and had superior accuracy when compared to the *Aranets*. Also, the *SwitchBot* sensors do not have a display, making them more discrete, as we considered the *Aranet* display may provoke questions about the device’s purpose from co-workers and supervisors. Hence, mid-season *SwitchBot* sensors were also piloted in some locations.

Subsequently we ran the sensors (4 *Aranets* and 8 *SwitchBots*) side by side from Jan 9-26, 2025, to assess agreement among readings. The range of differences and the percentage of time readings were different is set out in the table below.

	diff_temp		diff_RH
maximum diff	1.7	maximum diff	5
average diff	0.43	average diff	2.5
minimum diff	0.1	minimum diff	1
>0.6 C° difference	358	**>6% difference**	0
>0.6 C° difference	14.7%	**>6% difference**	0.0%
>1.0 C° difference	76	>10% difference	0
>1.0 C° difference	3.1%	>10% difference	0.0%
number of 10-min samples for each unit	2442		

For small, portable, low-cost units, we were adequately satisfied with the consistency of readings across multiple units of the *SwitchBots* as compared to the *Aranets*.

Appendix C. Acknowledging the vulnerability of MTFAWs

The structural vulnerability of MTFAWs has been discussed in terms of their vulnerability to occupational illness and injury, noted in the 2010 review of Ontario's occupational health and safety system led by Tony Dean, former Cabinet Secretary and Deputy Minister of Labour. They also face structural disempowerment to participate in injury and illness prevention, due to their immigration status and weak protections against reprisals. MTFAWs have expressed concern that if they speak up about OHS issues they may be sent back to their home countries or not rehired to return to Canada the following season, as has occurred to other MTFAWs whom they know. As such, OHS supports and interventions with these workers are important, but require consideration of the risk these workers may face through their participation.

To address the risk faced by participants, their confidentiality was ensured in the collection and reporting of the data. However, as part of the recruitment process, OHCOW outreach workers discussed the possible risk of having their participation in the project identified by unsupportive co-workers or employers, and the possibility of resulting reprisals from their employers. OHCOW outreach workers also discussed with workers that participation in this project aligned with the fundamental rights of Ontario workers to participate in OHS, as well as it being illegal for an employer to take action against a worker for participating in OHS, as outlined in the Occupational Health and Safety Act (OHSA). OHCOW outreach workers informed workers that in the case they felt concerned about, or faced a reprisal for their participation, to let us know as soon as possible, and that we would support the worker, and seek additional assistance from legal clinic partners, as well as the Ministry of Labour, Immigration, Training and Skills Development of Ontario. However, we informed workers that unfortunately, the outcome of such cases could not be assured, and therefore that the risk of facing a reprisal for participation in the project nonetheless was something for them to consider.

Workers who decided to participate in this project, consented to do so based on this consideration.

OHCOW recognizes that without effective anti-reprisal protections and addressing the structural vulnerability of these workers based on factors including their immigration status, important OHS work and interventions with MTFAWs will continue to come with a level of risk for members of these communities.

Appendix D. Assessing heat stress during work

In occupational hygiene, which is a discipline that evaluates occupational exposure hazards, there are well-established and recognized criteria for evaluating occupational exposures. These criteria have been researched and developed by the American Conference of Governmental and Industrial Hygienists (ACGIH) and are referred to as Threshold Limit Values (TLV®s). The Ontario Ministry of Labour, Immigration, Training and Skills Development (MLITSD) uses the ACGIH TLVs to promulgate occupational exposure limits (OELs) relating to chemical and physical hazards in the workplace, as specified in Ontario Regulation - [Control of Exposure to Biological or Chemical Agents, RRO 1990, Reg 833.](#)

While the MLITSD has not adopted the specific ACGIH TLV for Heat Stress and Strain, it has in the past used the "general duty clause" (See Occupational Health and Safety Act, section 25(2)(h) https://www.ontario.ca/laws/statute/90o01#BK47 ; https://www.ontario.ca/document/safety-guidelines-film-and-television-industry/appendix-c-adverse-weather-conditions) and recommended workplaces use the ACGIH Heat Stress and Strain TLV for the protection of a worker. Thus, the ACGIH Heat Stress and Strain TLV is an accepted method to evaluate heat stress exposures in Ontario. It combines the wet bulb globe temperature and other factors including the metabolic rate of the work involved, effects of clothing and work/rest cycles and acclimatization. We will start with a description of WBGT and then the other factors.

Wet Bulb Globe Temperature (WBGT)

The WBGT is a combination of three temperature measures:

1. The first is a "dry bulb" which measures the ambient temperature in the shade.
2. The second is a "wet bulb" which traditionally was a measurement of the temperature using a thermometer with a cloth "sock" over the bulb of the mercury thermometer. The cotton sock is soaked in distilled water that evaporates and cools the bulb of the thermometer. The difference between the dry bulb and the wet bulb is directly proportional to the relative humidity. The wet bulb component of the WBGT is a way of taking the relative humidity into account and makes up 70% of the calculation.
3. The third temperature measurement is the "globe temperature" which measures the radiant heat aspect of heat stress. Traditionally, this was a thermometer inserted into a matte black copper globe which was designed to absorb radiant heat.

The following equations show how these temperatures are combined to provide the WBGT.

... for indoor or shaded outdoor environments:

$$WBGT = 70\%\ T_{nwb} + 30\%\ T_g \qquad \text{(equation \#1)}$$

T_{nwb} = natural wet-bulb temperature

T_g = globe temperature

... for direct sunlight exposures:

$$WBGT = 70\%\ T_{nwb} + 20\%\ T_g + 10\%\ T_{db} \qquad \text{(equation \#2)}$$

T_{db} = dry-bulb temperature

While, previously, such measurements were taken with actual mercury thermometers, today electronic thermocouples are used instead (see productivity above and figure below).

Standard Electronic Heat Stress (WBGT) Monitor

These electronic heat stress monitoring machines are quite expensive (currently about $8000 for the unit in the Figure above) and thus not many such instruments are readily available in most workplaces. The unit in the Figure above has an accuracy of ±0.5°C between 0°C and 120°C for temperature and ±5% between 20 to 95% (non-condensing) for relative humidity.

Since many workplaces only have access to temperature and humidity measurements, equations have been derived by many different researchers to convert commonly available temperature and relative humidity data into WBGT measurements. In a journal article published in 2008, Liljegren et al. (Liljegren, James C., et al. "Modeling the wet bulb globe temperature using standard meteorological measurements." Journal of Occupational and Environmental Hygiene 5.10 (2008): 645-655), the authors created an algorithm to convert temperature and relative humidity measurements into an estimated WBGT. An Excel calculator is available online which makes this conversion available to users with the inputs of air temperature, relative humidity, solar radiation and windspeed for outdoor WBGT.

Once the WBGT is determined, the ACGIH TLV for heat exposure is categorized based on four additional factors: (1) metabolic rate categories for workers, (2), clothing adjustment values, (3) hourly work/rest cycles and (4) whether or not a worker is acclimatized to the heat as per ACGIH Table 3 below:

i. Metabolic rate category

The metabolic rate category is important to include since, under heat stress conditions, not only is the external environmental heat a stress on the body but physical activity also generates internal heat. The body's muscles are rather inefficient in that 70% of the energy the body uses to do physical activity is lost as heat – only 30% is actually translated into work.

The ACGIH standard is broken down into four metabolic rate categories:

- rest (assigned an average value of 115 Watts or W)
- light work (180 W); moderate work (300 W)
- heavy work (415 W)
- very heavy work (520 W)

In order to take into account both the external, environmental heat and the internally generated metabolic heat, the ACGIH has different WBGT criteria for each metabolic rate category.

ii. Clothing Adjustment Values: Adjusting for Clothing Resistance to Sweat Evaporation

Because extra clothing and personal protective equipment can prevent efficient sweat evaporation, the ACGIH TLV requires a Clothing Adjustment Value to be added to the WBGT measurement to account for this added heat stress burden. According to information provided by the worker on his typical work clothing, for the purposes of this evaluation, it is assumed that the worker was wearing "typical" work clothing (long sleeved shirt and long pants), although when it rained, he did wear a raincoat. For this reason, no adjustment was made (also, since the raincoat leaked, the rain on the skin would have counteracted that inhibition of sweat evaporation).

iii. Work/Rest Cycle

The work/rest cycle criteria are divided into four 15 minute per hour segments: 75-100% work/hr; 50-75% work/hr; 25-50% work/hr; 0-25% work/hr). It is important to note that heat stress assessments are conducted on an hourly, time-weighted average (TWA) basis, so if a worker spends part of the hour in a different location with different environmental conditions, a weighted average of the two measurements is calculated.

iv. Acclimatization

The final factor included in the ACGIH criteria is whether or not the worker is considered to be acclimatized to the heat. A working definition of acclimatization is provided in the TLV:

> *"Acclimatization requires physical activity under heat stress conditions like those anticipated for the work. With a recent history of heat stress exposures of at least 2 continuous hours for 5 of the last 7 days, a worker may be considered acclimatized for the purposes of the TLV. Acclimatization declines when activity under heat stress conditions is discontinued. A noticeable loss occurs after 4 days and may be completely lost in 3 weeks. A person may not be fully acclimatized to a sudden or episodic higher level of heat stress." (ACGIH (2022) - 11DOC-658-NPA Heat Stress and Strain TLV, pages 3-4)*

Applying these ACGIH Criteria to a MTFAW's Heat Exposures at Work
The ACGIH Table 3 states the assumption that exposed workers are working a 5-day work week at 8 hours per day with "conventional breaks." MTFAWs tend to work from early in the morning to early evening e.g. 11 hr days, with an hour break for lunch (no other breaks). Most work all 7 days each week, with some having shorter workdays on Sundays. The ACGIH criteria assumes that for a 5-day work week of 8 hours per day, there would be recovery time (16 hours per day and a 2-day weekend = a total of 128 hrs per week) when the worker would not be exposed to heat stress. However, most MTFAWs have 30 more hours of work exposure during the work week.
Thus, we can use the criterion of "at least 2 continuous hours for 5 of the last 7 days" applied to the measurements to determine whether the assumption of acclimatization is warranted. Using Table 3., from the TLV documentation the lowest WBGT values in the table are for 50-75% work at a "Heavy" metabolic rate (360-470 Watts). These values, 24°C WBGT for un-acclimatized workers and 27.5°C WBGT were selected as the most conservative criterion (i.e., the lowest threshold for) ascertaining acclimatization. Thus, any exposure above 24°C WBGT was considered to be heat stress exposure, and any exposures above 27.5°C WBGT was considered to eligible for comparison to the criteria of "at least 2 continuous hours for 5 of the last 7 days." An alternative approach was also taken in that one can use the criterion of "at least 2 continuous hours for 5 of the last 7 days" and determine at what WBGT level exposed workers could be considered acclimatized to. For example, if, in the last seven days, workers were exposed to at least 2 hours of continuous heat stress exposure at the level of 26°C WBGT for at least 5 of the 7 days, they could be considered "acclimatized" for exposures up to 26°C WBGT (i.e., not sufficient for the 27.5°C WBGT criterion for "ACGIH defined acclimatization" for "Heavy" work at a 50-75% work/rest regimen).

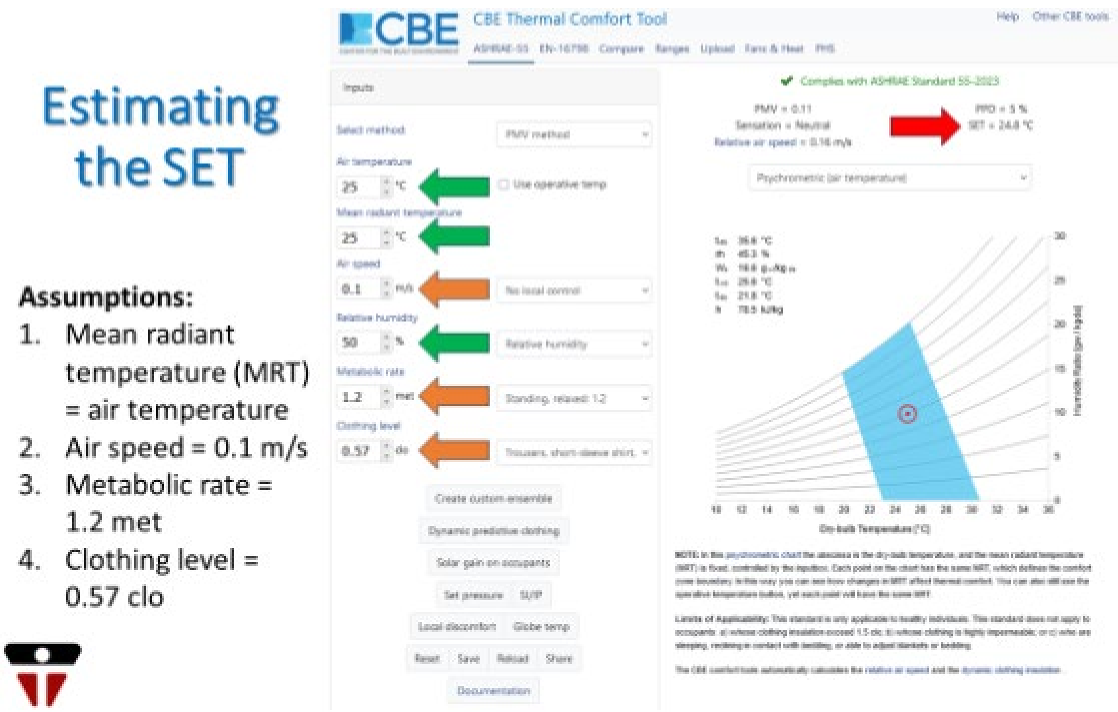
As shown in ***Figure 2.*** in the main body of this report, **outdoor workers do not achieve acclimatization status as determined by applying the ACGIH acclimatization criteria to the Lincoln weather station data for the summer of 2024 taking into account windspeed and solar radiation**.

OHCOW has simplified the ACGIH Heat Stress/Strain TLV by applying a number of assumptions and converting it into Humidex. OHCOW's Humidex Heat Response Plan is a simplification of the ACGIH TLV.

Appendix E. Calculating and choosing SET values for housing

> "The transient standard effective temperature (t-SET) metric is used to define and discern overheating events. The t-SET metric …accounts for the sleep mode, environmental variables (i.e., temperature, [mean radiant temperature](), [relative humidity](), air velocity) and occupant variables (i.e., hourly activity levels and clothing insulation)." (*p 4, Laouadi A, Bartko M, Lacasse MA. (2020) A new methodology of evaluation of overheating in buildings. Energy & Buildings 226 16 pp 110360 https://doi.org/10.1016/j.enbuild.2020.110360 [open access].*

Calculation of the SET can use different approaches. A commonly used one is that based on [ANSI/ASHRAE standards.]() The OHCOWs occupational hygienist used was the Berkeley Centre for the Built Environment's [CBE Thermal Comfort Tool.]()



Tartarini, F., Schiavon, S., Cheung, T., Hoyt, T., 2020. CBE Thermal Comfort Tool : online tool for thermal comfort calculations and visualizations. SoftwareX 12, 100563. https://doi.org/10.1016/j.softx.2020.100563

Choosing an acceptable SET value is based on Parsons (2014) text, *Parsons K (2014). Human Thermal Environments. The effects of hot, moderate and cold environments on human health, comfort and performance. 3rd Edn. Boca Raton, Florida et al CRC Press, Taylor & Francis Group [not open access]. In particular, Ch 11 Thermal Comfort pp 257-289.*

An earlier version of a table in this chapter was reproduced in Laouadi, A., et al. "Development of reference summer weather years for analysis of overheating risk in buildings." *Journal of Building Performance Simulation 13.3 (2020): 301-319.*

Laouadi and colleagues in their *Energy & Buildings* 2020 paper notes:

> "For healthy average age adults but with limited opportunities for adaptation, the threshold value of t-SET_d for an active occupant is set so that sweating is minimised. This corresponds to the upper limit of the comfort range with t-SET_d = 26 °C for un-acclimatized occupants and 27.2 °C for acclimatized occupants." And "For older people with limited opportunities for adaptation, the threshold value of t-SET_d for an active (wakeful) subject is set so that sweating is minimised." (p 5) Older MTFAWs (in their 60s) would be among the latter.

However, sleep disturbance is as important as sweating, particularly for MTFAWs trying to get a good night's rest. We rounded off the boundary SET value between the "comfortable and acceptable" and the "slightly warm, slightly unacceptable (slight sweating, vasodilation)" categories to 26°C (from 25.6°C) the typical accuracy of temperature sensors being ±0.3 to ±0.5°C. (See *Appendix B.* Comparing electronic Thermal Hygrometers above).

Glossary

- **Acclimatization:** The process by which bodily changes occur in a worker in response to heat stress exposure over time; these changes improve the worker's ability to tolerate heat stress *(ACGIH, 2022; Gosling et al., 2014)*.
- **Dehydration:** Loss or deficiency of water in body tissues caused by sweating, vomiting, or diarrhea. Symptoms include excessive thirst, nausea, and exhaustion (*OHCOW, 2024*).
- **Evaporation:** The most effective way to lose heat from the body from the conversion of liquid (sweat) to gas. The evaporation of sweat from the skin surface dissipates heat from the body and occurs more quickly with low humidity and high wind speeds. The ability to evaporate sweat is a major determinant in heat balance and thermal injury risk (*OHCOW, 2024*).
- **Heat strain:** The body's physiological response to heat stress *(ACGIH, 2022; Donoghue, 2004; WSN, 2014; Xiang et al., 2014)*.
- **Heat stress:** The net load of heat to which a worker may be exposed, taking into account metabolic heat production, environmental heat, and clothing and personal protective equipment (PPE) *(ACGIH, 2022; Donoghue, 2004; WSN, 2014; Xiang et al., 2014)*.
- **Heat related illnesses:** A spectrum of disorders, including heat cramps, heat exhaustion, and heat stroke and long-term conditions (e.g., kidney disease); caused by environmental exposure to heat (*OHCOW, 2024*).
- **Metabolic rate**: Rate of energy (and, consequently, heat) production of the body which varies between people and with the level of their activity *(ACGIH, 2022)*. If the rate of metabolic heat production is equivalent to the rate of heat lost, core body temperature does not change, as no heat is stored *(Cramer et al., 2022)*. If the rate of metabolic heat production exceeds the rate of heat loss, core body temperature increases as heat is stored *(Cramer et al., 2022)*.
- **Relative humidity:** The ratio of water vapour content of air to the maximum possible water vapour content of air at the same temperature and barometric pressure (*OHCOW, 2024*).
- **Radiation:** The transfer of heat, due heat waves being emitted from an object exposed to a temperature gradient, without the object coming into contact with any surface or object. The body gains heat from nearby hot objects that emit heat waves and loses heat in the same way to nearby cold objects (*OHCOW, 2024*).
- **Standard Effective Temperature (SET):** A temperature metric that factors in relative humidity, radiant heat, and air velocity, while also considering the anticipated metabolic rates and clothing levels.
- **Thermoneutral conditions**: A range of environmental temperatures where a body can maintain a stable internal temperature without increasing metabolic heat production or relying on evaporative cooling. Within this zone, heat production and heat loss are balanced, allowing the body to function at a minimal metabolic rate.
- **Threshold limit value (TLV):** The heat conditions at which healthy acclimatized individuals can reach thermal equilibrium under the ACGIH guidelines. For the purpose of the TLV, workers are considered acclimatized if they had recent heat stress exposures of at least two continuous hours, for five of the previous seven days *(ACGIH, 2022)*.

- **Wet bulb globe temperature (WBGT)**: A measure of environmental heat that takes into account: air temperature, humidity, air movement, and radiant heat (*ACGIH, 2022*).