Development of a new environmental index for outdoor and mist spray environments

Outline of research

**Background & Purpose**
Proposal of a new index to evaluate the thermal sensation in outdoor and mist spray environment.
- Thermal sensation is closely related to the heat exchange between human and environment.
- Mist spray system can be used to provide thermal relief on hot outside during summer.
- Survey researches are expensive and time-consuming.
- There is no appropriate environmental index for mist spray environments.

**Contents**

1. **Field experiment**
   - Measurement of environment factors
   - Survey research (mTSV, CSV, etc.)
   - Physiological responses (Temperature of skin and inside of mouth)

2. **Thermoregulation human model**
   - Predict the physiological responses
   - Gagge’s 2 node model

3. **Physiological responses**
   - Comparison of prediction and measured temps
   - Estimate the thermal state of the body

4. **Existing environmental indices**
   - Comparison of votes and existing indices

5. **New environmental index**
   - Adopt the concept of PMV
   - Calculate the heat storage by 2 node model
   - Correlation of heat storage and mTSV
   - Evaluate the thermal sensation in outdoor and mist spray environment

**Research flow for developing of new index**

- **Experiment**
  - Factors
    - Environment Air temp. MRT Airspeed Humidity
  - Human Clothing Metabolic
- **Physiology**
  - Skin temp. Core temp.
  - Votes mTSV CSV
- **Index**
  - PMV SET* ET* PET WBGT
  - New Index
- **Estimation**
  - Skin temp. Core temp. Wettedness Heat storage Heat loss
- **Human Model**
  - Sweating Blood flow Shivering
- **New Index**
  - Output
  - Validation Estimation
- **Validation**
  - Comparison of votes and existing indices
- **Estimation**
  - Calculation

- **INPUT**
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Thermal sensation and comfort of mist environment

Experiment 1
The effect of the mist spray system was verified by confirming the mTSV and CSV.

- Surveyed in before mist and after mist.
- Total of 342 women and 768 men participated in experiment freely.
- Environmental factors in mist environment were measured simultaneously.

<table>
<thead>
<tr>
<th>Experiment conditions</th>
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<tbody>
<tr>
<td><strong>Location</strong></td>
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<td>Shimbashi, Tokyo</td>
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Mist spray system in Shimbashi, Tokyo

1st VOTE Before mist

2nd VOTE After mist

The concept of experiment procedure

Results

- mTSV : 2.3 (Before) → 0.2 (After)
- CSV : −1.3 (Before) → 1.4 (After)

Feel ‘Hot’ : 98% (Before) → 33% (After)
Feel ‘Discomfort’ : 82% (Before) → 14% (After)

PDF of sensation vote results (mTSV & CSV)

The ratio of mTSV

The ratio of CSV
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Thermoregulation human model: evaluation and verification

**Experiment 2**
Field experiment has been conducted to verify whether Gagge’s 2-node model can be applied to the outdoor and mist spray environments.

**Results**
Mean skin temperature change in mist environment

- Calculation by 2 node model: $-1.0 \, ^\circ C$
- Experiment: $-0.7 \, ^\circ C$

\[ T_{sk} = 0.07 T_{head} + 0.35 T_{trunk} + 0.14 T_{forearm} + 0.05 T_{hand} + 0.19 T_{thigh} + 0.13 T_{calf} + 0.07 T_{foot} \]

\[ T_{core} \approx T_{mouth} \]
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Proposal of a new index using thermal sensation votes

mTSV vs. existing environmental indices
Only SET* might be able to predict the mTSV in mist spray environment.
Existing environmental indices are difficult to be utilized for predicting the thermal comfort.

New index: O-PMV
Adopting concept of PMV, propose a new environmental index O-PMV, by using the correlation between mTSV and the rate of heat storage.

\[ \text{PMV} = \frac{\delta TSV}{\delta S} \times S, \quad O-\text{PMV} = \frac{\delta mTSV}{\delta S} \times S \]

PMV: predicted mean vote, O-PMV: outdoor predicted mean vote
S: the rate of heat storage (W/m²), TSV: thermal sensation vote
mTSV: modified thermal sensation vote

\[ O-\text{PMV} = 0.04 \times S + 0.77 \text{ (Before mist)} \]
\[ O-\text{PMV} = 0.03 \times S - 0.27 \text{ (After mist)} \]