Biophysical Techniques in Skin Research

Measurement of TEWL

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Presentation Outline

• Introduction - History of TEWL methods
• A fresh Idea - The condenser-chamber method
• Condenser-chamber measurement examples
• Standardisation of TEWL measurements
• Calibration 1 - Membrane method
• Calibration 2 - New droplet method
• Mathematical model for TEWL measurement
• Conclusions
• Acknowledgements
Methods: ~35 Years ago ...

![Diagram of infared analyser and flow system used to measure water loss from skin]

**Flowing Gas [1]:** Complex laboratory apparatus.

Methods: ~25 Years ago ...

Nilsson's Open-Chamber Method [1]
Diffusion gradient measurement principle.

Miller et al’s Open-Cup Method [2]
Similar to above.
Appears to have been independently conceived.

Miller et al’s Closed-Cup Method [2]
Transient rise-time measurement principle.


Resulting Technology 1

Nilsson’s Open-Chamber Method

Evaporimeter
Servomed

Tewameter
Courage & Khazaka

DermaLab
Cortex Technology

This is currently the most widely used method for TEWL measurement.
Resulting Technology 2

Closed-Cup Method

Vapometer
Delfin

H4300
Nikkiso-YSI

Ventilated-Chamber Method

AS-TW1
Asahi Biomed

SKD1000
Skinsos
A Fresh Idea:- The Condenser-Chamber Method

**Closed-Chamber**

Shields from ambient air movements.

**Condenser**

Removes water vapour.
Controls the microclimate.

**Single RHT Sensor**

Improves accuracy & sensitivity.

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Resulting Technology 3

AquaFlux

Biox
It Works - eg TEWL Signals

Measurement times are comparable, but the fluctuations are much lower in condenser-chamber signals.

It Works - eg TEWL Measurements

Typical TEWL measurement repeatability without ambient climate control.

Mean TEWL = 54.4 gm$^{-2}$h$^{-1}$  CV = 3.8%

Mean TEWL = 8.30 gm$^{-2}$h$^{-1}$  CV = 2.4%
It just Works - Anywhere!

... your place or mine?
Standardisation of TEWL Measurements

Guidelines help to establish *best practice* in TEWL measurement.

But

The current guidelines [1, 2] consider open-chamber instruments only.

Therefore

Here’s my take on their relevance to condenser-chamber instruments.

Guidelines for the AquaFlux - Overview

The following recommendation remains valid:-

• Acclimatisation - you cannot take the *bio* out of bioengineering!

The following recommendations are not relevant:-

• Air movement - no effect
• Instrument handling - no effect
• Probe heating by skin - no effect
• Contact pressure - no effect
• Pause between measurements - no need, you can site-hop
• Measuring surface orientation - see next
Hold the probe correctly and you can measure surfaces of any orientation without significant bias.
The work of the TEWL Calibration Consortium [1] has established that:-


2. A new *droplet method* provides a more promising basis for TEWL calibration.

3. Traceability to National Standards can be established for the *droplet method*.

[1] The TEWL Calibration Project is sponsored by the UK Department of Trade and Industry. Project partners are:- EnviroDerm Services (project manager) (CL Packham and HE Packham), London South Bank University (RE Imhof, HE Packham and P Xiao), UK National Physical Laboratory (SA Bell, RM Gee and M Stevens), Biox Systems Ltd (EP Berg, RE Imhof and P Xiao), Dstl Porton Down (RP Chilcott & CH Dalton), and Gillette UK (A Stevens & N Weston).

1. Determine $J$ from cup weight loss rate.

**Problem:** $J$ depends on ambient conditions.

Temperature & RH are OK, but **boundary layer thickness** cannot be controlled accurately, see next slide.

2. Calibrate the instrument by equating $J_H$ with the $J$ from above.

**Problem:** The measurement head perturbs the flux, ie $J_H \neq J$. 
Membrane Calibration - Boundary Layer Problem

The flux through the membrane depends on boundary layer thickness.

The boundary layer thickness depends on air flow (see right) and geometry.

The biggest effects are at low air speeds.

Open-chamber instruments require low (zero ?) air speeds.

Problem!

NB:- for zero air speed, the boundary layer thickness is infinite!

Membrane Method Calibration Errors

NB:- The boundary layer thickness is in the range specified in the ASTM-96 standard.
Calibration 2 – New Droplet Method

1. Dispense a droplet of water into the calibration well.
2. Couple the TEWL measurement head to the well.
3. Record the flux vs time curve until all the water has evaporated.
4. Calculate the calibration factor from the area beneath the flux vs time curve.

Diagram:
- TEWL measurement head
- Calibration well
- Droplet (typically 1mg)
Droplet Calibration - Typical Data (AquaFlux)

The Q-Curve is calculated from the area below the Flux Curve. It gives a clear and immediate display of calibration accuracy.
Traceability for the droplet method is provided by a digital syringe, calibrated in accordance with MIL-STD-45662. The above calibration certificate claims an accuracy of 0.138% for a dispensed quantity of 0.8µL, with an unbroken chain of calibrations traceable to N.I.S.T.
Droplet Method with Different Instrument Types

This method can be used to calibrate all instruments capable of measuring flux time-series.
Droplet Method Repeatability (AquaFlux)

100 Repeat Calibrations:

CV = 2.1%
... But is it **RIGHT** ?

AquaFlux theory vs experiment:

\[
Cal(\text{theoretical}) = \frac{D_{VA}}{L_C - L_s} = \frac{2.42 \times 10^{-5}}{(16 - 9) \times 10^{-3}} = 3.46 \times 10^{-3} \text{ m s}^{-1}
\]

\[
Cal(\text{measured}) = 4.01 \times 10^{-3} \text{ m s}^{-1} \quad CV \approx 6\% \quad \text{(average over 10 instruments)}
\]

\[\therefore \Delta Cal \approx 14\%
\]

The closeness of the crude theoretical estimate to the measured calibration is remarkable. Given the independence of the two methods, this provides strong supporting evidence for the accuracy of the droplet method of calibration.
Mathematical Model for TEWL Measurement

To explore the effect of microclimate on TEWL measurement.

Assume:-

Steady-state diffusion

Evaporation at the SC surface

Coupled diffusion in condensed & vapour phases.

Sorption Isotherm relates $c_S$ to $x_S$
Sorption Isotherm

Data from Lévêque [1], digitised from an enlarged photocopy.

Electrical Analogy

Use electrical analogy of Fick’s Law, with equivalent circuits for skin & measurement devices.

Skin

Open-Chamber

Condenser-Chamber

\[ R_{SC} \] is Stratum Corneum Barrier Resistance.
Model Results

Calculated dependence of water vapour flux density on $1/R_{SC}$. This predicts a linear (Ohm’s Law) rise at low flux densities, where the SC barrier resistance $R_{SC}$ is high. Note that ambient humidity affects the open-chamber response but not the condenser-chamber response.
Conclusions from TEWL Measurement Model

At low TEWL, all techniques measure the same SC barrier resistance.
(because $R_{SC}$ controls the supply of water)

At high TEWL, open-chamber instruments read low.
(because of the high humidity at the skin surface, depending on ambient humidity)

The condenser-chamber has a larger linear range than the open-chamber.
(because the condenser maintains a lower humidity at the skin surface)
Conclusions

1. The condenser-chamber technology offers improved performance and ease of use.

2. The current *Guidelines* are outdated.

2. The droplet method offers an improved & traceable calibration.

3. The mathematical model can predict TEWL instrument response.
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