# RAPID MEASUREMENT OF TEWL WITH A CONDENSER-CHAMBER INSTRUMENT

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## 1. Aim

The aim of this study was to evaluate a protocol for the rapid measurement of TEWL using a condenser-chamber instrument.

## 2. Introduction

There are two main components to rapid TEWL measurement: (i) the measurement time itself and (ii) the recovery time before the next measurement can be started. The TEWL guidelines for open-chamber instruments [1, 2] recommend taking a recovery time into consideration before starting the next measurement. With unventilated-chamber instruments [3], speed is determined more by time spent clearing the chamber of accumulated vapour than by time spent measuring flux. Condenser-chamber instruments [4] are different, because the active microclimate control maintains consistent measurement conditions, permitting *site-hopping* measurement protocols without recovery time to be developed. This approach was evaluated using both in-vivo and in-vitro measurements.

Recent studies [5, 6] have indicated that the closed, unventilated-chamber method is capable of rapid TEWL measurement. Since *rapid* is an adjective without absolute meaning, we thought it worthwhile to relate the speed and performance of the condenser-chamber site-hopping protocol with an equivalent rapid-measurement protocol for an unventilated-chamber instrument.

## 3. The Condenser-chamber Method

The measurement chamber (see Figure 1) is a hollow cylinder, closed at its upper end by means of an aluminium condenser that is maintained at a precisely controlled temperature of -13.4 °C. Its lower end acts as a measurement orifice that is placed into contact with the test surface. The condenser controls the humidity in the measurement chamber independently of ambient conditions. It acts as a vapour sink by forming ice on its surface, thus creating a zone of low humidity in its immediate vicinity.

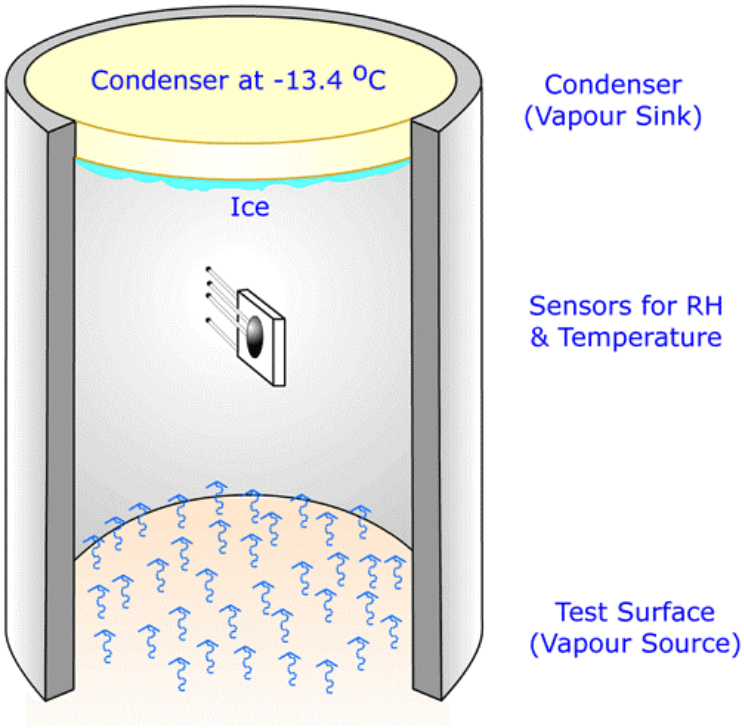


**Figure 1** Schematic diagram of a condenser-chamber.

The test surface acts as a vapour source, creating a zone of higher humidity in its immediate vicinity. This humidity difference causes water vapour to migrate from source to sink by passive diffusion. The water vapour flux is calculated from measurements of the associated humidity gradient and Fick's first law of diffusion.

## 4. In-vivo Protocol

The in-vivo protocol was designed to test the measurement uncertainties associated with rapid TEWL measurement. To this end, uncertainties associated with skin variability were reduced by confining the study to a single test area of a single volunteer in a single test session.

Seven test sites were marked on the left volar forearm of an elderly volunteer (REI), as illustrated in Figure 2.

**Figure 2** Test sites 1 - 7 on the left volar forearm.

The TEWL of the 7 sites was measured in rapid sequence by means of a condenser-chamber instrument (AquaFlux Model AF102, Biox Systems Ltd, UK) for a total of 12 repeats by moving the probe from site to site without any recovery delays (site-hopping). The ambient temperature and relative humidity during the test were 23.8 °C and 45%. The skin was acclimatised to these conditions for about one hour before the start of the measurements.

### 4.1 In-vivo Results

It took a total of 90 minutes to perform the 84 measurements defined in the protocol. An inspection of the recorded flux curves (Figure 3) revealed that all the measurements were of acceptable quality, with no evidence of sweat gland activity, despite the less than ideal ambient conditions. The TEWL map from these data and their uncertainties (±1 Standard Deviation) are shown in Figure 4.

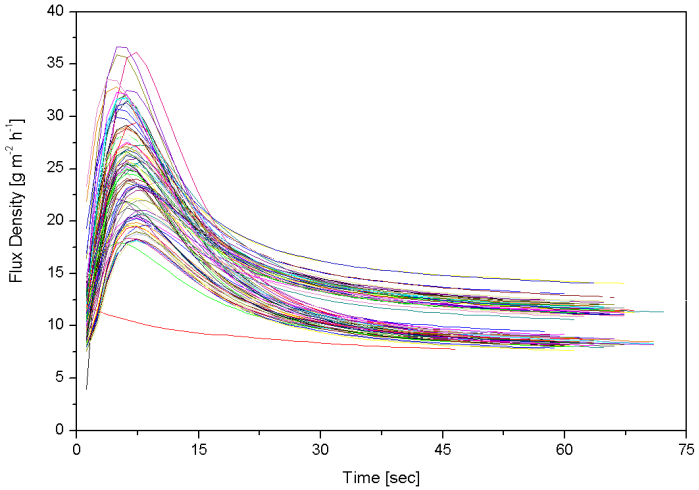


**Figure 3** Raw data from all 84 site-hopping measurements.

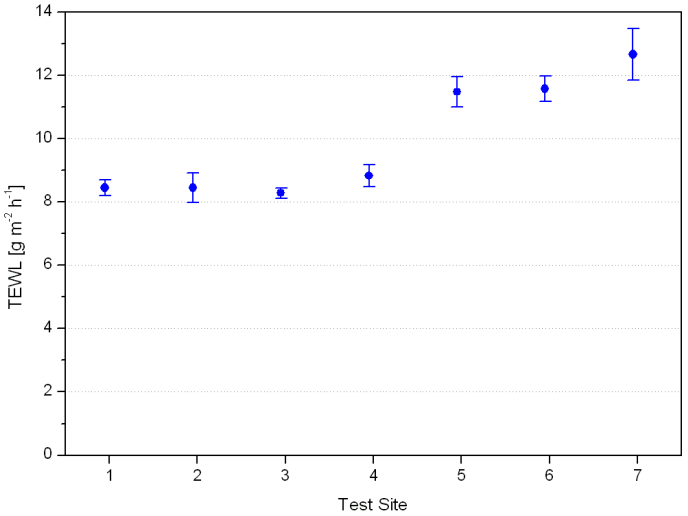


**Figure 4** TEWL map of the 7 sites shown in Figure 2. The error bars are ±1 Standard Deviation.

### 4.2 In-vivo Discussion

The measurements confirm the well-known trend of increasing TEWL from elbow to wrist. The measurement uncertainty, as indicated by the error bars, was found to be largest at the wrist (Standard Deviation = 0.81 g $m^{-2}$ $h^{-1}$, CV = 6.4%, Site 7) and smallest in the middle (Standard Deviation = 0.16 g $m^{-2}$ $h^{-1}$, CV = 2.0%, Site 3). These values are similar to what is observed with a more conventional protocol, where the instrument is parked between measurements [4]. There is therefore no discernible loss of precision associated with the site-hopping protocol.

A question now arises about the origin of the observed uncertainties, whether they are properties of the skin or properties of the measurement method. Accuracy of repositioning in repeat measurements is indicated, given that the largest uncertainty was observed at the site next to the wrist, where the skin is known to be inhomogeneous. However, a more complete answer can only be provided by a more detailed assessment of measurement uncertainties in the absence of in-vivo skin uncertainties.

## 5. In-vitro Water Vapour Flux Source

Uncertainties associated with the measurement method itself were assessed by means of the in-vitro water vapour flux source shown in Figure 5. The upside-down design differs from the conventional wet cup design described by Pinnagoda *et al* [1] in eliminating the air gap between water surface and membrane. Direct contact between water and membrane allows membranes of higher diffusion resistance to be used, thus reducing systematic errors associated with changes of humidity and diffusion resistance on the outside of the cup, as ambient conditions change, or when measurement heads of different design are brought into contact with the membrane.

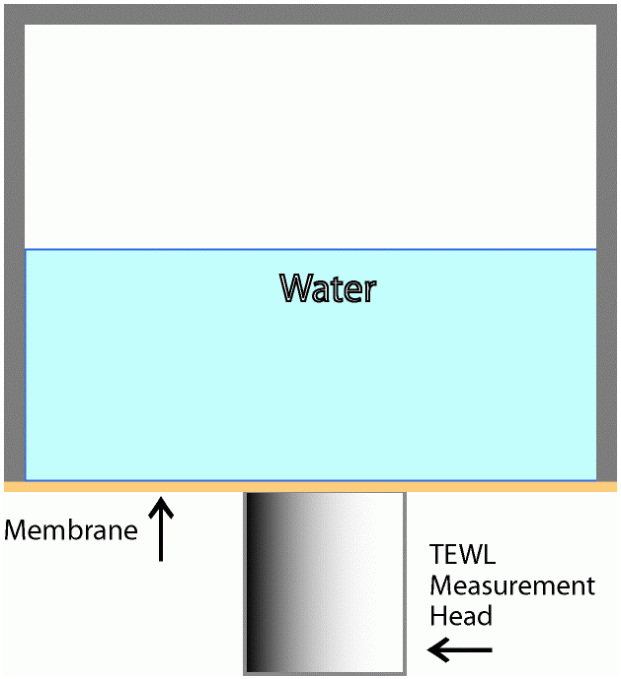


**Figure 5** In-vitro water vapour flux source, where water is in contact with a permeable membrane.

## 6. In-Vitro Protocol

Initial experiments showed that a Sil-Tec (Technical Products Inc, USA) Type 500-5 membrane produced a stable water vapour flux of comparable magnitude to the volar forearm TEWL measured above. The site-hopping protocol was simulated by breaking the contact between membrane and measurement head for 1-3 seconds after every measurement.

### 6.1 In-vitro Results

The results from 200 repeat measurements are shown in Figure 6. The average flux density works out to 7.46 g $m^{-2}$ $h^{-1}$. The uncertainties are Standard Deviation = 0.09 g $m^{-2}$ $h^{-1}$ and CV = 1.2%.

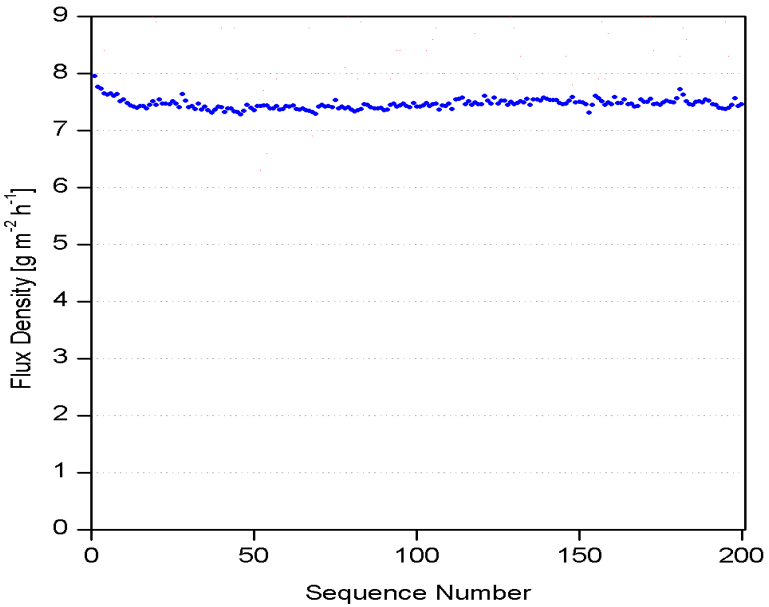


**Figure 6** In-vitro repeat measurements using a simulated site-hopping protocol.

### 6.2 In-vitro Discussion

The results show that the uncertainties of simulated site-hopping AquaFlux measurements with the in-vitro water vapour flux source are considerably smaller than those with in-vivo skin. The in-vivo uncertainties shown in Figure 4 can therefore be attributed to the skin rather than to the instrument or the protocol. Skin heterogeneity with less than perfect repeat-placement of the measurement head is the most likely cause.

## 7 Comparison with Unventilated-chamber Method

Equivalent in-vivo and in-vitro experiments to the above were performed with an unventilated-chamber instrument (VapoMeter, Delfin Technologies Ltd, Finland). A site-hopping protocol is not possible with this instrument, because the water vapour captured during a measurement needs to be allowed to escape before the next measurement can be started. Instead, the contact with the test surface was confined to the measurement phase only, and the next measurement was initiated as quickly as possible after completion of the ventilation phase of the previous measurement. The DelWin software was used to minimise data display delays. This protocol accords with the manufacturer's recommendations in the instruction manual.

### 7.1 In-vivo Comparison

TEWL values of an equivalent 7 sites of the volar forearm of the same volunteer were measured in rapid sequence for a total of 12 repeats. The ambient temperature and relative humidity were 20 °C and 42%. The skin of the test area was acclimatised to these conditions for about one hour prior to the start of the measurements. A comparison of results with the equivalent AquaFlux results of Section 4.1 is shown in Figure 7.

Three features are apparent in the comparison:-

1. Total measurement time for the 84 VapoMeter measurements was found to be 53 minutes, as compared with 90 minutes for the AquaFlux.

2. There is broad agreement between VapoMeter and AquaFlux measurements, characterised by a Pearson correlation coefficient of R = 0.82.

3. The uncertainties of the in-vivo VapoMeter readings are significantly larger than those of the AquaFlux.

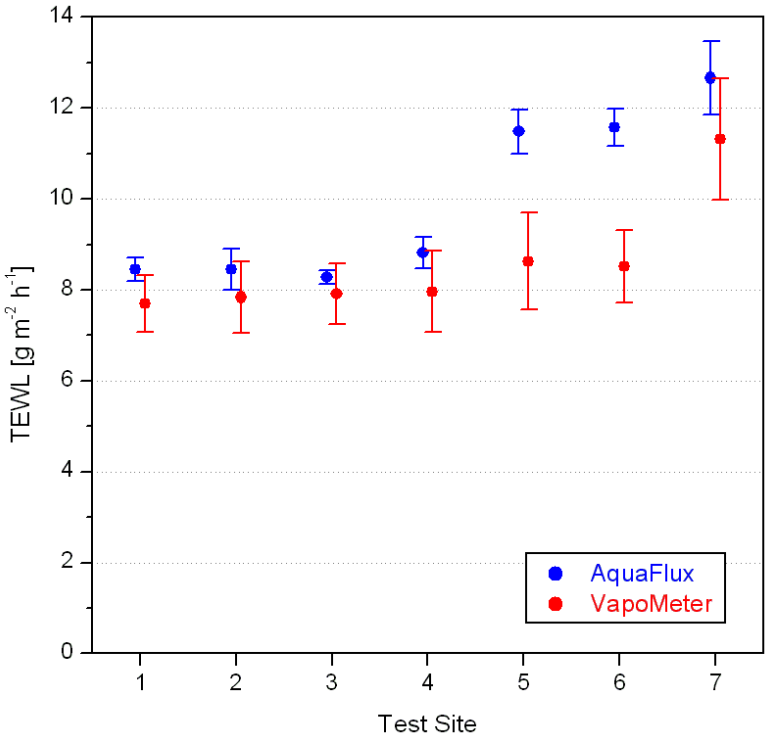


**Figure 7** In-vivo comparison between TEWL measurements using the condenser-chamber AquaFlux (same data as in Figure 4) and the unventilated-chamber VapoMeter. The error bars are ±1 Standard Deviation.

The larger uncertainties of the VapoMeter readings may reflect (i) skin property changes from one study to the next or (ii) instrumental uncertainties. In-vitro measurements with a homogeneous and stable source were therefore performed to study (ii) in the absence of (i).

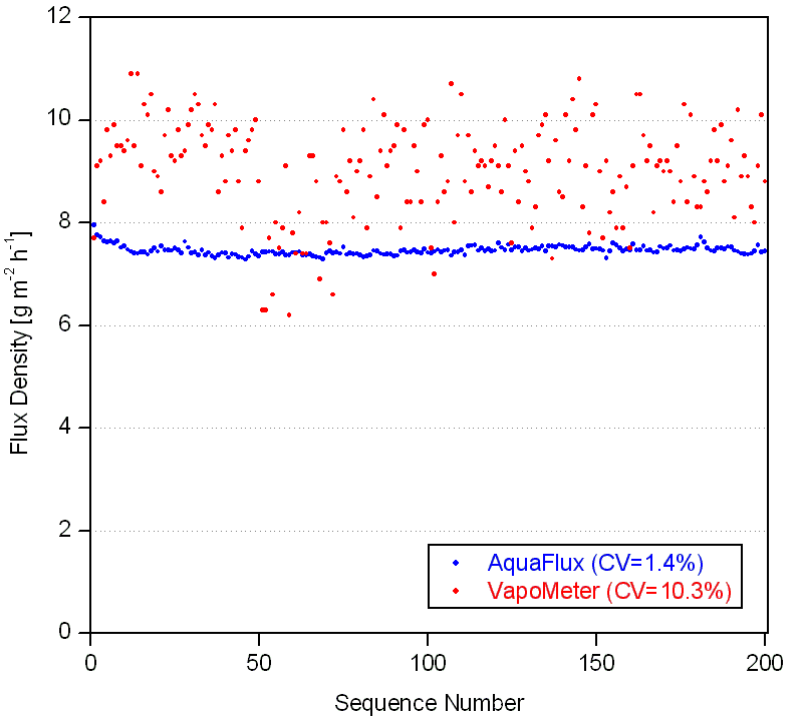


**Figure 8** In-vitro comparison between flux density measurements using the condenser-chamber AquaFlux (same data as in Figure 6) and the unventilated-chamber VapoMeter.

### 7.2 In-vitro Comparison

Figure 8 shows the results from 200 VapoMeter measurements using an in-vitro source of the type described in Section 5. The average flux density works out to 9.02 g $m^{-2}$ $h^{-1}$. The uncertainties are characterised by a Standard Deviation of 0.93 g $m^{-2}$ $h^{-1}$ and a CV = 10.3%. Thus, the in-vitro VapoMeter measurement uncertainties are comparable in magnitude to the in-vivo VapoMeter measurement uncertainties shown in Figure 7. This indicates that instrument properties rather than skin properties dominate in these measurements.

## 8. Summary

The main finding is that the accuracy and sensitivity of condenser-chamber AquaFlux TEWL measurements can be maintained in a rapid site-hopping protocol. The in-vivo measurement uncertainties were found to be significantly larger than comparable in-vitro measurement uncertainties, as summarised in Table 1. This indicates that the observed in-vivo measurement uncertainties can be attributed to the skin rather than to the protocol or instrument. Skin heterogeneity with less than perfect repeat-placement of the measurement head is the most likely cause.

Table 1: Summary of Uncertainties

| | | In-vivo Test Site | | | | | | | In-vitro |
|---|---|---|---|---|---|---|---|---|---|
| **Instrument** | **Quantity** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| AquaFlux | CV % | 3.0 | 5.4 | 2.0 | 4.0 | 4.2 | 3.6 | 6.4 | 1.2 |
| VapoMeter | | 8.2 | 9.9 | 8.5 | 11.2 | 12.3 | 9.4 | 11.9 | 10.3 |

Comparative measurements using an unventilated-chamber VapoMeter instrument were found to be characterised by uncertainties that were significantly larger than comparable AquaFlux uncertainties, as summarised in Table 1. The average value of CV of ~10%, whether in-vivo or in-vitro, indicates that the observed in-vivo measurement uncertainties were attributable to instrumental fluctuations rather than to the skin in this case.

The mean measurement repeat-time of 64 seconds for the AquaFlux site-hopping protocol was found to be larger than the 38 seconds of an equivalent rapid measurement protocol with the VapoMeter instrument. However, measurement uncertainties should also be taken into account in the comparison, given that AquaFlux measurement times can be reduced in a trade-off with measurement quality.

## 9. References


[1] J Pinnagoda, RA Tupker, J Agner and J Serup, *Guidelines for Transepidermal Water Loss (TEWL) Measurement*. A Report from the Standardization Group of the European Society of Contact Dermatitis. Contact Dermatitis 22, 164-78 (1990).

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