# A comparative study of microclimate in mattresses; Clinical and financial factors for consideration

where skin meets fabric

dartex

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## Introduction

"Any surface that comes into contact with skin has the potential to alter microclimate by changing the rate of evaporation of moisture and the rate at which heat dissipates from the skin. The overall effect on microclimate is dependent on numerous factors, including nature of the support surface itself (i.e. what it is made from, how the material is conformed, what sort of cover it has)" [1]

This study evaluates different polyurethane monolithic coatings used as mattress cover materials (tickings) and grades them gravimetrically. The impact of the composite structure in which these are used is then assessed to determine the relationship between the performance data of the cover material and the microclimate management of the total bed system.

In addition the durability of the materials with respect to cleaning by a selection of disinfectants promoted for use in the medical industry, are assessed. Recent work in this area has demonstrated a direct relationship between the moisture vapour transmission properties of the polyurethane polymer and the propensity to damage [2].

By careful selection of both the system and the cover it is proposed that an acceptable balance between durability and microclimate can be found that is in advance of the systems currently on the market.

The method of moisture vapour transmission through monolithic coatings has been widely described in many articles [3]

The fundamental laws relating to diffusion of a gas or vapour through a polymer were proposed by Fick in the 19th century. Fick's main hypothesis states that the rate of transfer through unit area of a section, F(x), is proportional to the concentration gradient measured normal to the section, i.e.

**Fick's First Law of Diffusion**

$$F(x) = -D(\partial C/\partial x)$$

**C is the concentration of diffusing substance**
**x is the distance normal to the section**
**D is a constant, diffusion coefficient.**

From this we can derive the definition of flux:

**Definition of Flux**

$$F(x) = D(C1 - C2)/t$$

**C1 is the concentration of vapour on one face of a sample.**
**C2 the concentration on the opposite face.**
**ℓ is the thickness**

Leading to the more familiar transmission rate:

**Transmission Rate**

$$Q/At = D(C1 - C2)/\ell$$

**Q is quantity of substance**
**A is area of the sample**
**t is time**
**ℓ is the thickness of the sample**

This is the basis for most measurements of moisture vapour transmission, or breathability. It is commonly expressed as grams/m2/24 hours and as this measure is based on weight these methods are often described as gravimetric.

Such gravimetric measurements of moisture loss are convenient methods to compare materials to one another, but often do not directly relate to the user experience

However it is more relevant in the management of microclimate in the medical environment to consider the clothing, bedding and support surfaces as a barrier to moisture vapour transmission.

In an ideal scenario the atmosphere in immediate proximity to the skin would be approaching that of a standard atmosphere (50-65%RH). In association with this, and considered to be of increasing importance in the management of pressure ulcers, is the maintenance of a regulated and normal range of skin temperature [4],[1],[12].

As such the method of determining resistance to water vapour transmission and thermal resistance measured by a sweating guarded hotplate as defined in ISO 11092 [5]. In this test fabric is placed above a porous plate. The plate is heated to a constant temperature and water is channeled into the metal plate, simulating perspiration. As water vapor passes through the plate and the fabric, it causes evaporative heat loss. This results in the system requiring energy in order to maintain a constant temperature. This energy allows the calculation of Ret, the resistance to evaporative heat loss.

**Resistance to Evaporative Transmition**

$$Ret = \frac{(pm-pa)A}{H - \Delta He} - Ret0$$

Ret0 is the bare plate resistance
pm=water vapour partial pressure at the surface
At 40% pa is 2,250Pa.
ΔHe is a correction term

The use of barrier textiles in medical mattress covers is vital as they create a waterproof barrier to ensure that bodily fluids do not contaminate the core of the mattress and represent a potential vector for infection between patients [7].

## Method

Four sample materials have been selected for testing as they represent a wide range of breathability and polyurethane polymer types. The moisture vapour transmission was assessed gravimetrically using the Index method as defined in BS3424 [6], Table 1. Here samples are maintained in a controlled environment and the amount of mass loss in a period of time is determined relevant to a standard woven polyester textile. This value is only measured once the system has reached equilibrium.

Two of these fabrics were also measured using ISO 11092 as a fabric alone, Table 2. In these tests these were measured with the face intended to be closest to the patient's skin against the area of high humidity to replicate the intended end use.

The method used for the measurement of the mattress composite is directly base on the sweating guarded hotplate, but is inverted and measured over the full composite including bedding as intended in enduse.[8], see Figure 2, Table 3.

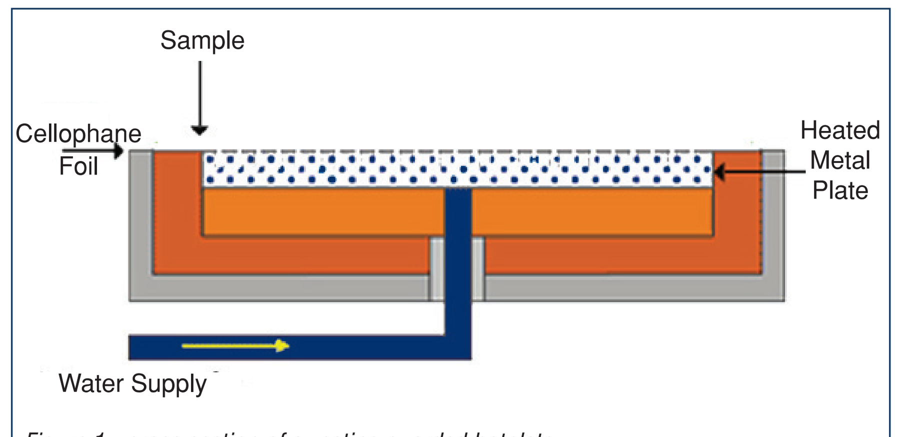


*Figure 1 - cross section of sweating guarded hotplate*

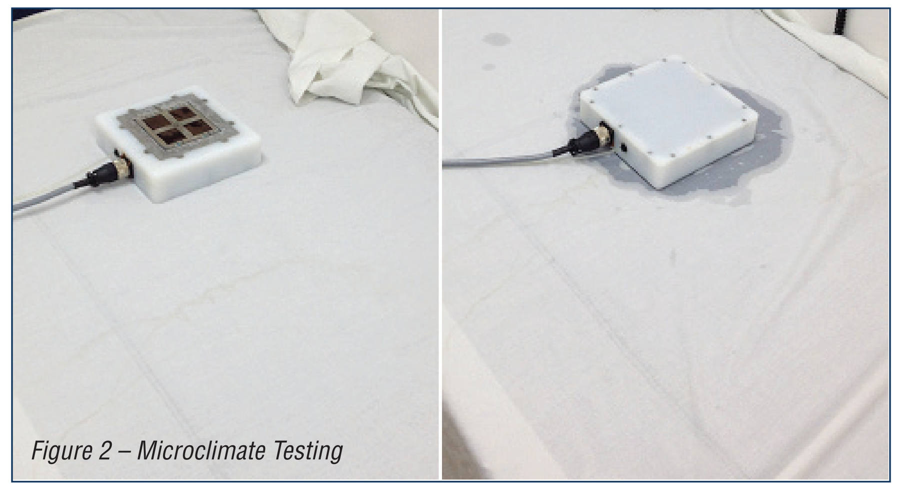

*Figure 2 – Microclimate Testing*

An 'in house' test method was developed by Stryker Medical [9] in order to replicate the multiple applications of cleaning agent over a mattress covers life. In summary this consists of mounting a sample with the patient face uppermost on a flat metal housing and applying the disinfectant to the surface at the recommended concentration from the supplier. In this test the cleaning agent is not rinsed from the surface after application and in respect to this it represents a worst case scenario as in drying the concentration of the components may increase, Table 4

After exposure in this manner the surface was then assessed visually and under magnification with observations on discolouration, textural changes, potting and delamination, handle and resistance to water penetration. The latter parameter was measured under ISO 1420 [10].

## Conflict of Interest

Due to the proprietary information included in this poster permission must be sought before referencing or using this data in future work.

## References

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## Acknowledgements

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## Results

**Table 1**

| BS3424 Part 34 method 37 - Water Vapour Permeability Index | |
|---|---|
| Sample Reference | WVPI |
| **Fabric A** | **10%** |
| **Fabric B** | **57%** |
| **Fabric C** | **79%** |
| **Fabric D** | **28%** |

**Table 2**

| ISO 11092: Sweating Guarded - Hotplate | |
|---|---|
| Sample Reference | $R_{et}$ (m2Pa/W) |
| **Fabric A** | 204.76 |
| **Fabric C** | 14.16 |

**Table 3**

| System Measurement of $R_{dry}$ | |
|---|---|
| Sample Reference | $R_{et}$ (Km2/W) |
| Open gel + air movement and Fabric A | 0.390369 |
| Open gel + air movement and Fabric B | 0.267444 |
| Open gel + air movement and Fabric C | 0.364246 |
| Open gel + air movement and Fabric D | 0.39981 |

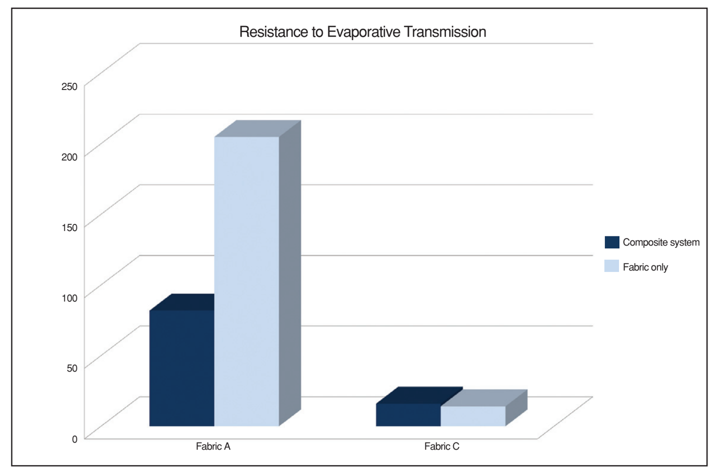
**Table 4**

| System Measurement of $R_{wet}$ | |
|---|---|
| Sample Reference | $R_w$ (m2Pa/W) |
| Open gel + air movement and Fabric A | 81.87281 |
| Open gel + air movement and Fabric B | 64.94515 |
| Open gel + air movement and Fabric C | 15.99120 |

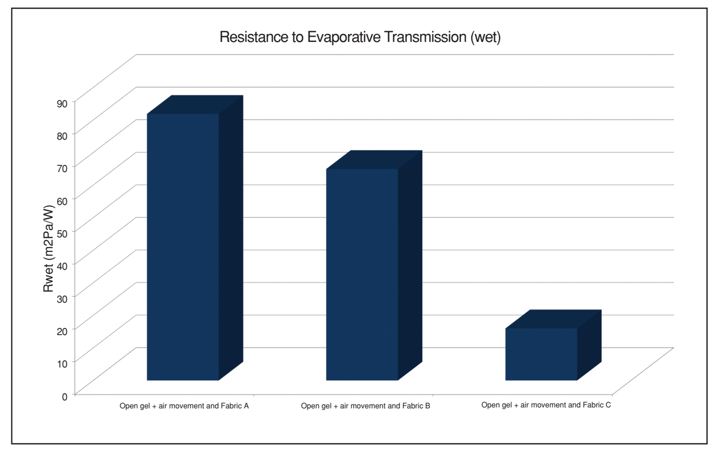
**Table 5**

| Durability against cleaning agents | | |
|---|---|---|
| Sample Reference | Visual Observation | Resistance to water penetration (kPa) |
| Fabric A | Compatibility with majority of cleaning agents but accelerated hydrogen peroxide caused failure see Figure 3 | >50kPa |
| Fabric B | Compatibility with majority of cleaning agents but accelerated hydrogen peroxide caused failure see Figure 3 | >50kPa |
| Fabric C | Wide range of materials resulted in delamination and damage of the coating | 0-5kPa for most reagents |
| Fabric D | Median range of compatibility issues seen | 0-30kPa depending on system |

Graphical representation of impact of core




Graphical representation of impact of cover




## Discussion

As can be seen from the results above the amount of resistance to moisture vapour transmission can vary widely depending on the nature of the polyurethane mattress cover fabric used and the core of the mattress on which it is used. The impact of air flow has a very large effect on this. This is particularly evident on the lowering of the Resistance to evaporative transmission in the wet stat with the low breathability material, Fabric A. Here the exchange of high humidity air with that of lower humidity rapidly increases the moisture gradient and thus promotes the transmission of water vapour across the barrier. However the low moisture vapour transmission of this material has ultimately limited the performance of the core.

With the highly breathable fabric the system has been able to perform to a much greater effect and is less of a barrier than the fabric alone.

The composite data point for Fabric B shows that there has been less restriction on the system. Work is continuing to understand the drivers for performance for the system as a whole.

Although the results show that the increase in breathability of the cover material does have a deleterious effect on the durability there is strong evidence that the formulation of Fabric B represents an acceptable balance point between these two inversely related properties. It is expected that further development work will lead to further improvements in this.

## Clinical Relevance

The selection of the mattress cover fabric is integral to the overall performance of the finished support system. The moisture vapour transmission allows control of the microclimate. High humidity and temperature have been shown to promote the development of pressure ulcers. However it must be acknowledged that the covers need to have an effective method of being cleaned without resulting in damage that exposes patient to possible sources of infection. Although it would be possible to simply have single patient covers even here there may be a risk of self re-infection if a cover is damaged and stays in use. Regular replacement of covers may partially solve this problem but it places a great financial burden on the hospital.

Finding the appropriate balance between these factors and the care level required by the patient [11] is critical in optimizing the patient care and device availability within budgetary constraints.

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