Infection Risk Modeling

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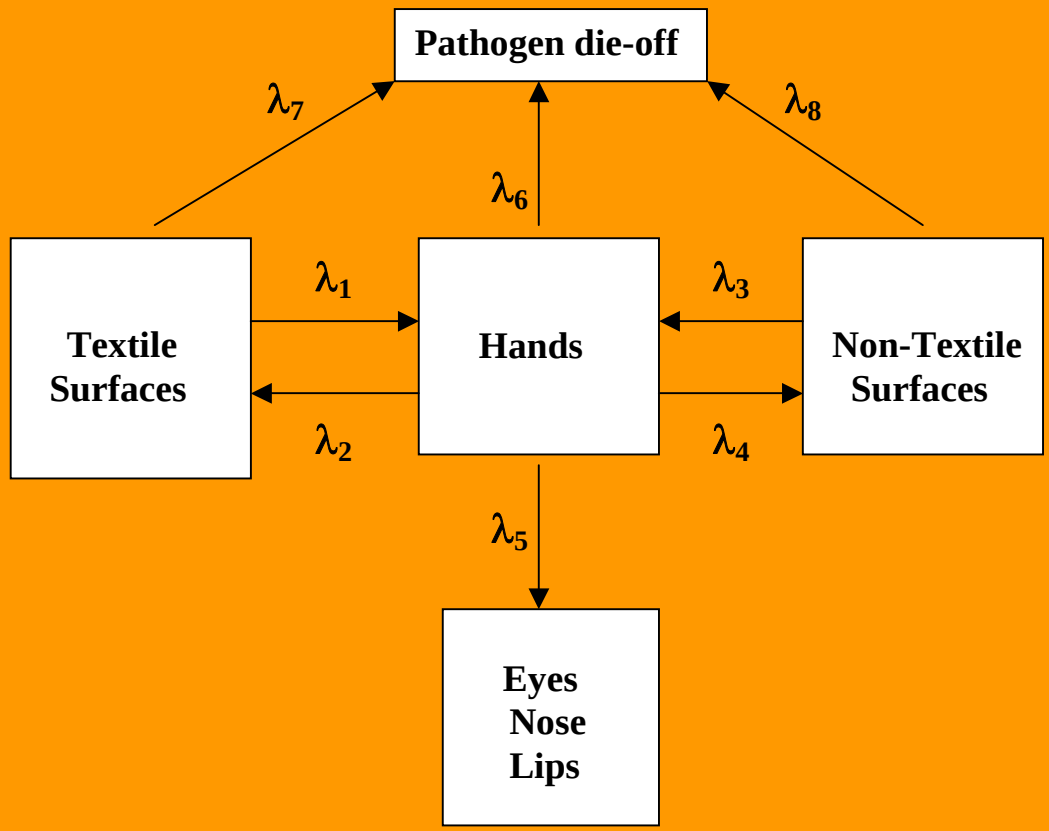
Respiratory Tract Infections

- 25% or more of respiratory tract infections are due to surface-to-hand-to-face contact.

- To evaluate the potential efficacy of an antimicrobial textile finish, I developed a quantitative model of infection risk due to this transmission route.

Required Model Inputs

- pathogen concentration on surfaces
- rate of hand contact with surfaces
- rate of hand contact with facial targets
- fraction of pathogens transferred from the areas touched
- survival rate of pathogens on surfaces
- survival rate of pathogens on hands


Pathogen die-off
λ7
λ6
λ8
Textile Surfaces
λ1
λ2
Hands
λ3
λ4
Non-Textile Surfaces
λ5
Eyes
Nose
Lips

Rate Values

- The λ quantities are first-order rates, or fractions per unit time. The larger the λ value, the faster the rate of transfer.

- Consider the die-off rate on the hands. If $\lambda_6 = 0.69$ per hour, the pathogen half life on the hands is 1 hour. If $\lambda_6 = 2.8$ per hour, the half life on the hands is ¼ hour.

Rate Values

- The transfer rate from the hands to the face depends on the touch rate to the face (F, per hour), the hand area that touches (A, cm^2), and the fraction of pathogens transferred (about 0.35) per cm^2-touch:

$$\lambda_5 = F \times A \times 0.35$$

- For simplicity, if one fingertip always touches, A = 2 cm^2.

The Value for F

- We observed ten volunteers for three hours each while they sat at a desk doing office work.

- The average contact rate for all facial targets was 16 per hour (range: 1 to 35 touches per hour).

Model Inputs

- **Input values can vary from pathogen to pathogen. Some may survive well on surfaces and the hands, others may die off rapidly. Concentrations on surfaces can vary with emission characteristics.**

- **Input values can vary from person to person and from scenario to scenario. Again, the facial touch rate varies at least 35-fold between persons.**

Model Output

- **The model output is numerically computed by a Markov chain technique via a computer code.**

- **The mathematical details are not important here. Suffice it to say that the model accounts for the changes in viable pathogen numbers on surfaces and the hands over time, and the number of viable pathogens transferred to facial targets.**

Model Output

- **The primary model output is the dose of viable pathogens delivered to facial targets over a specified exposure time.**

- **If we have information on (1) the fraction of the external dose that reaches internal tissue receptor sties, and (2) the infectivity of the pathogen, we can relate this external dose to infection risk.**

External Dose

- **In its simplest form, the pathogen dose depends on the touch rate to the face (say, 16 per hour), the average viable pathogen concentration on the fingers (C, # per cm^2), the finger contact area per touch (say, 2 cm^2), the pathogen transfer efficiency (0.35), and the duration of time the fingers are contaminated (T, hour):**

$$\text{External Dose, } D = 16 \times C \times 2 \times 0.35 \times T$$

Internal Dose

- It is likely that only a fraction ε (0 to 1) of the external dose reaches internal tissue receptor sites. For respiratory tract pathogens transmitted via hand contact, these receptors would be in the oro- and naso-pharyngeal regions.

- To my knowledge, there are no experimental data on the value of ε for any pathogen. A default assumption might be $\varepsilon = 0.5$.

Respiratory Tract Infection Risk

- **Infection risk is most simply estimated by:**

  $$\text{Infection Risk} = 1 - \exp(-\alpha \times \varepsilon \times \text{Dose})$$

  where α is the probability of infection due to a single pathogen. The value of α depends on the specific pathogen.

- **In general:** $\alpha = \log(2) \div ID_{50}$.

Model Utility

- **Due to the variability in model input values, there is no one set of values that can be said to represent all pathogens and all exposure scenarios.**

- **However, for a specified scenario, we can use the model to examine the potential efficacy of applying an anti-microbial finish to textile surfaces by estimating the relative reduction in external dose.**

An Example

- Consider that a health care worker (HCW) attends a bedridden patient who emits pathogens in coughs and secretions.
- It is reasonable that at least 95% of the emitted pathogens would deposit on textile versus non-textile surfaces.
- It is reasonable for the HCW to touch textile surfaces at least 2-fold more frequently than non-textile surfaces.

An Example

- However, it is reasonable that the pathogen would exhibit at least a 2-fold higher die-off rate on textile versus non-textile surfaces, because porous surfaces promote desiccation of the pathogen.

- In addition, the transfer efficiency to the hands from textile surface is about 5-fold less than from a non-textile surface.

An Example

- **Given these numbers, touching textile surfaces would lead to transferring about 4-fold more viable pathogens to the HCW's facial targets than touching non-textile surfaces.**

- **If an antimicrobial finish on textile surfaces acted very rapidly, we would expect an approximate 80% reduction in the external pathogen dose due to hand contact with facial target membranes.**