Introduction to Infectious Disease Modelling and its Applications

Course Description

Intensive online course: 15th – 26th June, 2020

LONDON SCHOOL of HYGIENE & TROPICAL MEDICINE

Public Health England

Introduction

Infectious diseases remain a leading cause of morbidity and mortality worldwide, with HIV, tuberculosis and malaria estimated to cause 10% of all deaths each year. Outbreaks of Ebola in recent years have led to unprecedented numbers of deaths and cases. New pathogens continue to emerge in animal and human populations, as demonstrated by the emergence of SARS in 2003, of Highly Pathogenic Avian Influenza (HPAI) in poultry and humans in 2004/2005, swine flu in 2009, MERS CoV in 2013, Zika in 2016 and recently, SARS-CoV-2.

Mathematical models are being increasingly used to understand the transmission of infections and to evaluate the potential impact of control programmes in reducing morbidity and mortality. This two week intensive online course is intended to introduce professionals with an interest in infectious diseases in either developing or developed countries to this exciting and expanding area. The emphasis will be on developing a conceptual understanding of the basic methods and on their practical application rather than the manipulation of mathematical equations.

The level of difficulty is appropriate for people with high school level of mathematics and is similar to that of the book "An Introduction to Infectious Disease Modelling", published in 2010, which was written by two of the course organizers (Emilia Vynnycky and Richard White). The book is based on material from this course, which has been running face-to-face since 2001.

Course structure

The course comprises 4 sections, as follows:

Section 1: Basic methods and motives for developing infectious disease models

This section is designed to introduce participants both to the basic methods for developing models of the transmission dynamics of infectious diseases and to the applications of these models. It starts with a lecture giving an introduction to the major concepts used for studying the epidemiology of infectious diseases (the basic reproduction number, incubation periods, serial intervals, herd immunity) and continues with an introduction to the main types of models that can be employed.

Participants learn about the basic methods for setting up deterministic models (difference and differential equations) and will gain practice and confidence in setting up simple models using spreadsheets and a specialist, user-friendly modelling package (Berkeley Madonna). Participants will gain an understanding of the insights into infectious disease dynamics that models can provide, such as the factors influencing the periodicity of disease incidence for immunizing infections (e.g. the incubation period, basic reproduction number, seasonal transmission, vaccination and control programmes) and how the models can be applied to determine optimal control strategies for outbreaks involving new pathogens as well as for endemic infections.

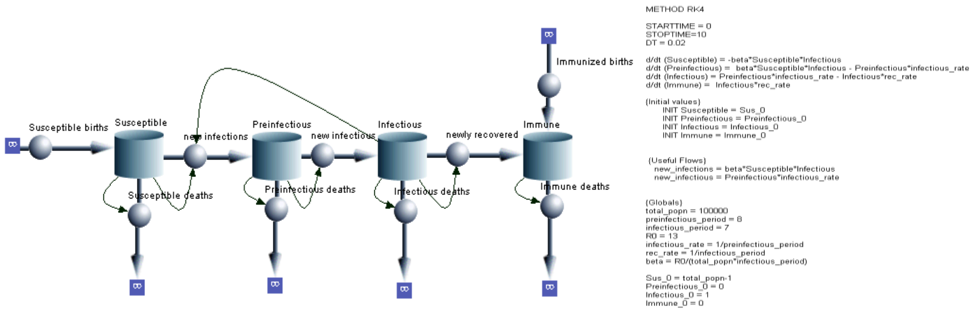

Figure 1: Example of different approaches which can be used to set up models using Berkeley Madonna. Models can be set using either flow diagrams or equations. Participants can work with the approach that they prefer during the course.

Section 2: Analysis of data and applications of modelling of seroprevalence data

Section 2 deals with the methods for analysing seroprevalence or other data on past infection, how they can be used for elucidating past trends in infection incidence and for studying the transmission dynamics and predicting the control of infections. The section starts with a session on how to analyse and interpret seroprevalence data, which is followed by a second lecture describing different fitting methodologies. During the subsequent sessions, participants will examine different data sets and estimate (age-dependent) infection incidences ("forces of infection") for high and low infection transmission settings, using rubella as an example.

These estimates are then used to analyse how control policies can lead to reductions in transmission but increases in infection incidence in adult life (and other unexpected events), depending on the study setting. Participants will also study how seroprevalence data can be used to estimate mixing patterns of subgroups in given populations and how different contact patterns between individuals affect the impact of control.

Section 3: Additional methods and dynamics - stochastic and network modelling, health economics and sensitivity analyses

This section provides an introduction to several methodological aspects of modelling, namely stochastic and network models, health economics and sensitivity analyses.

Stochastic models are often used to describe the transmission dynamics of infections in small populations, for example, for predicting the course of outbreaks and critical population sizes for the persistence of infection. This section introduces participants to the basic methods for setting up stochastic models of outbreaks and the long-term dynamics of directly transmitted infections.

Modelling studies are increasingly including health economics analyses, for example, to estimate the cost-effectiveness of an intervention and such estimates can often be persuasive when making health policy decisions. Modelling studies also need to use sensitivity analyses to determine the effect of different assumptions or inputs on predictions of the incidence or control of an infection. In this section of the course, the basic principles of health economic analyses and sensitivity analyses are introduced in a lecture and practical. An optional lecture discussing methods for fitting models to data and methods for sensitivity analyses is also scheduled.

The success of control programmes greatly depend on the extent to which different individuals are connected, for example, the individuals that each person contacts and the contacts of those persons. These issues are illustrated in a lecture on network models, which try to capture such detailed contact patterns and have been used in modelling the transmission and control of sexually transmitted infections and Foot and Mouth Disease.

There is increasing interest in "real-time modellng", which uses data collected in real-time to infer what is currently occurring with the transmission dynamics of infection and whether ongoing interventions are making an impact. This section of the course concludes with a live lecture giving an overview of methods and examples of real-time modelling in practice.

Section 4: Applications of modelling

The sessions in this section are designed to illustrate several major areas of applications of mathematical models, the transmission of sexually transmitted infections (STIs) and HIV, tuberculosis and malaria, The sessions are run in parallel and there is a short review for these sessions on the final day.

Teaching methods

The teaching will be delivered using self study material, consisting of interactive distance learning material, recorded lectures and computer practicals, live review sessions and live lectures. A typical day centres around a 2 hour period (14:00-16:00 UK time), during which there will be a live review of material covered in the previous self-study period, which will be followed by a live lecture. At the start of the course, students will be provided access to the self study material, which will allow participants can work through the self study material at their own pace and participation in the live sessions is optional.

Live lectures by modellers are scheduled during the course, covering topics outside the core material. These lectures are designed to provide further perspectives on the areas of application of modelling and attendance is entirely optional.

Whilst working on the self study material, participants will be able to post questions relating to the material in the self study session on a forum, and questions will be answered as soon as possible.