



# Journal of Applied Sciences

ISSN 1812-5654

**science**  
alert

**ANSI***net*  
an open access publisher  
<http://ansinet.com>

## A Proposed Mathematical Model of Influenza A, H1N1 for Malaysia

S.A.A. Karim and R. Razali

Department of Fundamental and Applied Sciences, Universiti Teknologi PETRONAS,  
Bandar Seri Iskandar, 31750 Tronoh, Perak Darul Ridzuan, Malaysia

**Abstract:** The current flu pandemic caused by the Influenza Type A virus called H1N1 started in late March 2009 and to date has infected more than 1 million persons all over the world with more than 15,000 deaths in 182 countries. Malaysia is one of the countries has registered about 12,000 cases with 77 fatalities. In this study we discuss our preliminaries studies of the development of mathematical model to help understand the dynamics of an epidemic, to design treatment and develop a control strategies such as a vaccination program or quarantine policy.

**Key words:** Pandemic, influenza a (H1N1), mathematical model, control strategies

### INTRODUCTION

There exist various type of epidemics such as gonorrhea, HIV/AIDS, BSE, Foot and Mouse Disease (FMD), measles, rubella, pertussis (Allman and Rhodes, 2003; Caldwell and Ram, 1999; Gurevich, 2009; Li *et al.*, 1999; Roberts and Heesterbeek, 2003) and the most recent is SARS and current global epidemics that is H1N1. The first cases of Swine Influenza virus A, H1N1 were firstly reported on 9 April 2009 in Mexico and later this pandemic was spreading around the globe. The World Health Organization (WHO) is asking the people to study and develop a mathematical model of the spread of swine flu, also known as Influenza A, H1N1 as concern grows that actual case numbers may be far higher than the agency's tally of officially diagnosed infections. According to WHO statistics, (<http://www.who.int/csr/disease/swineflu/en/index.html>) at 27 September 2009, there have 343 298 influenza-like-illness (ILI) cases of H1N1 and report at least 4108 death cases. Transmissions of ILI continue to increase. In fact in Malaysia, so far we have 12,210 ILI cases and 77 death cases (<http://h1n1.moh.gov.my/>).

Although, medical advanced have reduced the consequences of some infectious diseases, however individual features of diseases and societies must be taken into account. However, understanding the dynamics of disease transmission is essential to addressing them and now we realized that mathematical modeling definitely will play a role here. Once a model has been formulated that captures the main features of the progression and transmission of a particular disease in a population, it can be used to predict the effects of

different strategies for disease eradication or control. Yet even though the infectious disease modeling is inexact, but we can try to reduce the error of approximation and give us an enormous potential to help improve human lives (Allman and Rhodes, 2003). Therefore, the mathematical modeling is an important tool for understanding the dynamics of an epidemic, planning and evaluating the spread of diseases. In this study we present the selective literature review that has been done all over the world and we will investigate and develop the appropriate mathematical model for Malaysia.

### MATERIALS AND METHODS

This project will identify and make a description of the mathematical modeling of infectious diseases especially for Influenza A, H1N1 and based on a selective review of the literature and the infectious diseases data in Malaysia. A lot of work on influenza modeling has been done all over the world over the past 30 years based on the infectious diseases data (Caldwell and Ram, 1999; Chowell *et al.*, 2004; Gurevich, 2009; Li *et al.*, 1999; Roberts and Heesterbeek, 2003). For example in 1985, a Soviet-American team demonstrated that, on the basis of air travel, it was possible to reconstitute retrospectively the 1968 Hong Kong pandemic through a worldwide network of 52 large cities (Allman and Rhodes, 2003). A new strain of virus (H3N2) had spread all over the world in less than two years, in a population entirely susceptible to it. From city to city, epidemiological stations of surveillance had noted that from the time the strain appeared, an epidemic wave followed. The underlying assumption was that air travel was the main route of

international dispersion of the virus. In France, a similar methodology applied which data on regular railroad traffic between 22 metropolitan districts were used (Boyce and Di Prima, 2010). However, so far there is no tool available for simulating and forecasting the spread of influenza A, H1N1 in Malaysia. Based on the graph plotted from the available data from Ministry of Health as in Fig. 1, We will propose a mathematical model of H1N1 for Malaysia.

**Proposed mathematical model of h1n1 for Malaysia:** In this study, the authors describe basic concepts in the mathematical modeling of infectious diseases. The appropriate mathematical model related to the spread of influenza is investigated and developed. The model will involve a network of 13 states in Malaysia in a discrete space domain. The time-domain is continuous. Within each state (index  $i$ )  $n_i$  is the population size. These  $n_i$  are classified in four groups, according to their status concerning infection with the influenza A (H1N1) virus namely as the number of susceptible persons, the number of contagious persons incubating the virus without symptom of the disease, the number of ill persons and the number of recovered persons. Based on the spread of the virus, the model also been develop which involves two processes: First, the dynamic of contacts in a given state between susceptible and contagious persons. Secondly, the person that travels between the states which bring contagious persons from one place to another. In the process of developing this model, the population size and the transportation fluxes are assumed constant We also assumed that all persons except those with the illness may travel from one state to another.

**Mathematical model:** In order to develop a mathematical model of H1N1 for Malaysia, we have to study various models of infectious diseases. Among the models are: SIS model, SIR model and SEIR model.

We will define and explain each model as follow:

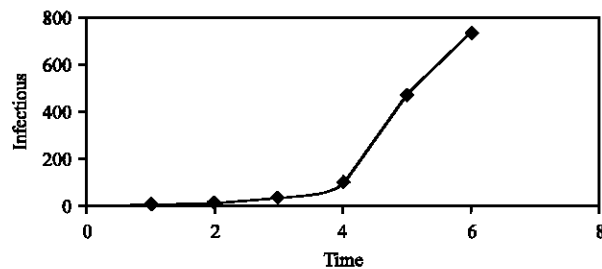


Fig. 1: Number of Infectious cases in Malaysia from June 2009 to July 2009 (weekly data)

**The SIS model:** The SIS model is the simplest model in which an infection does not confer immunity. Thus susceptible become infected and then become susceptible again upon recovery as in the Fig. 2.

**The SIR model:** The SIR model (Allman and Rhodes, 2003; Bradie, 2006; Brannan and Boyce, 2009) has been proven a relatively good predictor for infectious diseases. This model can be described in the Fig. 3. It means that when an individual becomes infected, he/she becomes immediately infectious and is able to infect other peoples. However, the infected peoples may recover from the disease and hence move to a recovered class, where they will be no longer infectious while acquiring immunity to the disease.

**The SEIR model:** The SEIR model is the same as the SIR model, except that before the individual becomes infectious, of cause he/she will be exposed to the environment. The model can be described as in the Fig. 4.

**The SEIRS model:** Based on the models that we were discussed above, we choose and proposed the SEIRS model (Li *et al.*, 1999) as indicated in the Fig. 5, as an appropriate mathematical model of H1N1 for Malaysia. This model same as the SEIR model, but the recovered individuals will be considered again as a susceptible person.

In order to develop this model, we need to make some assumption. Below the details:

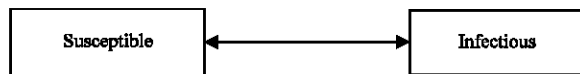


Fig. 2: SIS Model

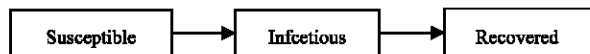


Fig. 3: SIR Model

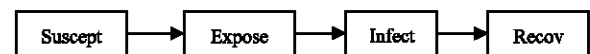


Fig. 4: SEIR Model

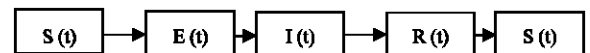


Fig. 5: SEIRS Model

- A portion of  $S(t)$  of the population that is susceptible to the disease
- A portion of  $I(t)$  that already have the disease and are contagious
- There are also those who are temporarily immune and become susceptible after some time
- All new born are assumed to be susceptible
- Individuals are susceptible, then exposed, then infectious and then recovered with the possibility of becoming susceptible again with the rate constant of loss immunity equal to  $\delta \geq 0$
- The parameter  $\epsilon > 0$  and  $\gamma > 0$  are the rate constant that exposed individuals become infectious and the rate constant the infectious individuals become recovered, respectively
- Thus, we have  $1/\epsilon$  and  $1/\gamma$  are the mean latent and infectious periods, respectively
- We also assumed that the birth rate constant and the natural death rate also constant and are equal and denoted by  $\nu > 0$
- The transmission coefficient is  $\beta > 0$

We also assume that the population is randomly mixed up, that is the susceptible and contagious are evenly distributed over the area that they living.

$S(t)$  = No. of susceptible individuals at time  $t$   
 $E(t)$  = No. of exposed (not yet infectious)  
 $I(t)$  = No. of infected individuals at time  $t$   
 $R(t)$  = No. of recovered with temporary immunity at time  $t$

So, we have ordinary differential equations to model the H1N1 spread (Edwards and Penny, 2008; Simmons and Krantz, 2007; Zill, 2009):

$$\begin{aligned} \frac{dS}{dt} &= -\beta IS + \nu - \nu S + \delta R \\ \frac{dE}{dt} &= \beta S - (\epsilon + \nu)E \\ \frac{dI}{dt} &= \epsilon E - (\gamma + \nu)I \\ \frac{dR}{dt} &= \gamma I - (\delta + \nu)R \end{aligned}$$

where,  $S(t)$ ,  $E(t)$ ,  $I(t)$  and  $R(t)$  denote the functions of the populations that are susceptible, exposed (not yet infectious), infectious and recovered with temporary immunity at time  $t$ , respectively and  $S(t) + E(t) + I(t) + R(t) = N$ .

**RESULTS AND DISCUSSION**

The fundamental concept of mathematical modeling of infectious diseases is a better understanding of the

course of an epidemic by solving the differential equations system above. Modeling studies based on past influenza epidemics suggest that the rise of the epidemic curve can be slowed at the beginning of the epidemic by isolating ill persons and giving prophylactic medications to their contacts. Later on in the course of the epidemic, restricting the number of contacts (e.g., by closing schools) may mitigate the epidemic but will only have a limited effect on the total number of persons who contract the disease. Actually analyzing the spread of an infectious disease such this Influenza A, H1N1 disease not only requires mathematical modeling knowledge and computational skills but also must be a good understanding of the biological processes behind the disease under study.

**CONCLUSION**

Mathematical modeling is a valuable tool for understanding the dynamics of an epidemic and for planning and evaluating interventions. Based on the data available from Ministry Of Health (MOH) or maybe hospitals in Malaysia, we will find and develop the appropriate mathematical modeling of H1N1 for Malaysia. For further work, based on all the parameters estimated, the reproduction number, (the average number of secondary infections generated by an infectious individual into a fully susceptible population)  $R_0$  will be determined and to ensure whether the H1N1 in Malaysia is pandemic or not.

**ACKNOWLEDGMENT**

The authors wish to thank Universiti Teknologi PETRONAS for the financial support given to present the paper in this conference.

**REFERENCES**

Allman, E.S. and J.A. Rhodes, 2003. *Mathematical Models in Biology an Introduction*. Cambridge University Press, New York, USA.  
 Boyce, W.E. and R.C. Di Prima, 2010. *Elementary Differential Equations and Boundary Value Problems*. 9th Edn., John Wiley and Sons, New York.  
 Bradie, B., 2006. *A Friendly Introduction to Numerical Analysis*. Prentice Hall, New Jersey.  
 Brannan, J.R. and W.E. Boyce, 2009. *Differential Equations with Boundary Value Problems: An Introduction to Modern Methods and Applications*. John Wiley and Sons, New York.

- Caldwell, J. and Y.M. Ram, 1999. *Mathematical Modelling: Concepts and Case Studies*. Kluwer Academic Publishers, Dordrecht, Netherlands.
- Chowell, G., C. Castillo-Chavez, P.W. Fenimore, C.M. Kribs-Zaleta, L. Arriola and J.M. Hyman, 2004. Model parameters and outbreak control for SARS. *Emerging Infect. Dis.*, 10: 1258-1263.
- Edwards, C.H. and D.E. Penny, 2008. *Differential Equations and Boundary Value problems Computing and Modeling*. 4th Edn., Prentice Hall Inc., New Jersey.
- Gurevich, K.G., 2009. Formal kinetics of H1N1 epidemic. *Theor. Biol. Med. Modelling*, 6: 23-23.
- Li, M.Y., J.S. Muldowney and P.V.N. Driessche, 1999. Global stability of SEIRS model in epidemiology. *Can. Applied Mathematics Q.*, 7: 409-425.
- Roberts, M.G. and J.A.P. Heesterbeek, 2003. A new method for estimating the effort required to control an infectious disease. *Proc. R. Soc. Lond.*, 270: 1359-1364.
- Simmons, G.F. and S.G. Krantz, 2007. *Differential Equations: Theory, Technique and Practice*. McGraw Hill, Singapore.
- Zill, D.G. and M.R. Cullen, 2009. *Differential Equations with Boundary-Value Problems*. 7th Edn., Brooks Cole, USA.