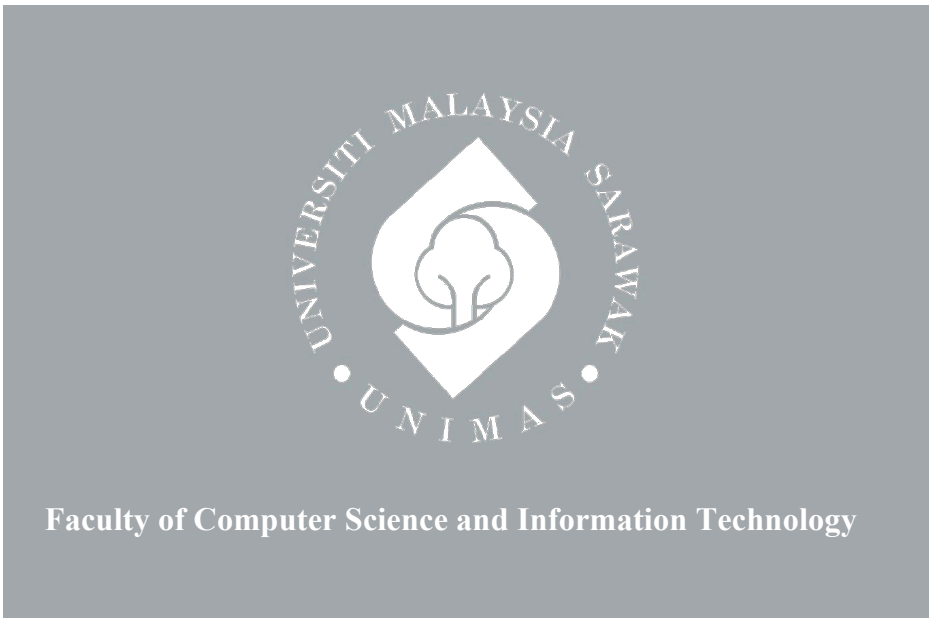


# Computational Modeling of SEIPR Model for the Transmission Dynamics of Hand, Foot and Mouth Disease in Sarawak

**Chan Sze Jan**

**Master of Science**
**2019**

# Computational Modeling of SEIPR Model for the Transmission Dynamics of Hand, Foot and Mouth Disease in Sarawak

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A thesis submitted

In fulfillment of the requirements for the degree of Master of Science

(Computational Modeling)

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**DECLARATION**

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. It is original and is the result of my work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been accepted for any degree and is not concurrently submitted in candidature for any other degree.

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**ABSTRACT**

This thesis aims to develop a suitable model to describe the transmission dynamics of hand, foot and mouth disease (HFMD) specifically in addressing the insight on the ability of the virus to survive in the respiratory secretion and stool of a patient for a period of time in order to predict the periodic cycle of HFMD infectious cases more accurately. This was found necessary since a basic SIR (Susceptible-Infectious-Fully recovered) model only provide a basic framework to discuss the characteristic of HFMD. Biological characteristics, which are incubation period, infectious period and post-infectious virus shedding period are known to be the factors for the virus spreading. Thus, to provide a complete study framework based on the biological factors of HFMD, basic SIR model was extended to become SEIPR (Susceptible-Incubation period-Infectious-Post infectious virus shedding-Fully recovered) model whereby the incubation period and post-infectious period together with the existing infectious period to act as infected compartments were incorporated. The numerical results of the model were compared with the actual 2006 HFMD infectious data. There is no significance difference between the numerical simulation and the actual data by using the SEIPR during the first wave of the outbreak for ten weeks. Then, SEIPR model is being verified by analyzing the HFMD outbreaks from year 2010 to 2014 and the results during the first wave of the outbreaks are well matched with the actual cases. Hence, with the inclusion of the transmission coefficient gained from incubation period patients, which is $\beta_1$ and post-infectious patients, which is $\beta_6$ together with the transmission coefficient from infectious individual, which is $\beta_5$ to susceptible in the improvement SEIPR model, the numerical simulation results reached a consensus that

the incorporated infected compartments are able to predict the HFMD cases during the first wave of the outbreaks for ten weeks. Furthermore, SEIPR model provides two main parameters that have been evaluated include basic reproductive number, $R_0$ and the threshold value. The values of $R_0$ calculated are between 1.13 to 1.54, indicating the outbreaks of the disease occurred from year 2010 to 2014. Meanwhile, the threshold value as minimum proportion of the population to create the liability of the disease spreading for each case was found to be in the range 6500 to 9000 people. It is observed that with higher $R_0$, the transmission coefficient is higher and the threshold value is smaller, which means more people can be infected. Hence, to reduce the number of infected cases, the transmission coefficients need to be reduced, thus, the number of any contact person within the infected region needs to be controlled, so that the impacts of the outbreaks can be reduced.

**Keywords**: Hand, foot and mouth disease, SIR model, SEIPR model, incubation period, post-infectious virus shedding period.

***Model SEIPR bagi Pemodelan Pengiraan untuk Jangkitan Dinamik Tehadap Penyakit Tangan, Kaki dan Mulut di Sarawak***


***ABSTRAK***

*Tesis ini menumpu kepada penghasilan satu model yang sesuai untuk menerangkan tentang jangkitan dinamik yang disebabkan oleh penyakit tangan, kaki dan mulut terutamanya melihat kepada keupayaan virus kekal hidup dalam rembesan pernafasan dan najis pesakit dalam tempoh tertentu dan membuat jangkaan keputusan yang lebih tepat dalam pengiraan kitaran berkala jangkitan kes-kes penyakit tangan, kaki dan mulut. Ini adalah diperlukan kerana penggunaan model asas iaitu model SIR (Orang yang belum dijangkiti-orang yang dijangkiti-orang yang sembuh selepas jangkitan) hanya menyediakan rangka kerja yang asas dalam penerangan sifat-sifat penyakit tangan, kaki dan mulut. Sifat-sifat faktor biologi iaitu tempoh pengeraman, tempoh semasa jangkitan dan tempoh selepas jangkitan adalah faktor-faktor penyebaran jangkitan. Dengan itu, model asas SIR telah dikembangkan kepada model SEIPR (Orang yang belum dijangkiti-orang yang dijangkiti tanpa gejala-orang yang dijangkiti dengan gejala-orang selepas dijangkiti tetapi gejala telah hilang-orang yang sembuh selepas jangkitan) supaya satu rangka kerja yang lengkap berdasarkan sifat-sifat faktor biologi penyakit tangan, kaki dan mulut di mana model SEIPR yang baharu dibina ini telah menggabungkan tempoh pengeraman dan tempoh selepas jangkitan bersama dengan tempoh semasa jangkitan untuk bertindak sebagai komponen-komponen jangkitan. Perbandingan di antara keputusan jangkaan dan keputusan sebenar data 2006 penyakit tangan, kaki dan mulut telah dilakukan. Keputusan berangka simulasi dengan data sebenar didapati tiada perbezaan yang ketara semasa gelombang pertama penyebaran wabak penyakit dalam tempoh sepuluh minggu. Kemudian, model SEIPR telah disahkan penggunaannya dengan*

*menganalisiskan penyebaran penyakit tangan, kaki dan mulut dari tahun 2010 hingga tahun 2014 dan keputusan semasa gelombang pertama penyebaran wabak penyakit adalah sepadan dengan data sebenar. Oleh itu, dengan penambahan pekali penyebaran dari orang yang dijangkiti tanpa gejala iaitu* $\beta_1$ *dan orang selepas dijangkiti tetapi gejala telah hilang iaitu* $\beta_6$ *bersama dengan pekali penyebaran dari orang yang dijangkiti iaitu* $\beta_5$ *kepada orang yang belum dijangkiti dalam model SEIPR, keputusan simulasi berangka mencapai persetujuan di mana penggabungan komponen-komponen jangkitan berupaya membuat jangkaan keputusan kes-kes penyakit tangan, kaki dan mulut dalam tempoh sepuluh minggu semasa gelombang pertama penyebaran wabak penyakit. Dua parameter yang telah dinilai termasuk nombor penyebaran asas,* $R_0$ *dan nilai ambang.* $R_0$ *yang terhasil didapati berada dalam lingkungan 1.13 hingga 1.54 menunjukkan wabak penyakit tersebar dari tahun 2010 hingga tahun 2014. Pada masa yang sama, nilai ambang setiap kes yang didapati adalah dalam lingkungan 6500 hingga 9000 orang yang diperlukan supaya wabak boleh tersebar. Keputusan menunjukkan dengan* $R_0$ *yang tinggi, pekali penyebaran adalah tinggi dan nilai ambang adalah kecil, ini bermakna, lebih ramai orang akan dijangkiti. Bagi mengurangkan kes-kes jangkitan, pekali penyebaran hendaklah dikurangkan, jadi, jumlah keupayaan orang berjumpa di kalangan ramai dengan yang dijangkiti hendaklah dikawal supaya impak yang diterima oleh penyebaran wabak boleh dikurangkan.*

***Kata kunci****: Penyakit tangan, kaki dan mulut, model SIR, model SEIPR, tempoh pengeraman, tempoh selepas jangkitan.*

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| | |
|---|---|
| $\alpha_1$ | transmission coefficient of susceptible individuals getting infected for SIR model (per time) |
| $\alpha_2$ | the rate at which a recovered individual loses its immunity for SIR model (per time) |
| $\alpha_3$ | the rate at which an infectious individual fully recovered for SIR model (per time) |
| $\beta_1$ | transmission coefficient of susceptible individuals getting infected by incubation period individual for SEIPR model (per time) |
| $\beta_2$ | the rate at which an asymptomatic patient developing symptoms for SEIPR model (per time) |
| $\beta_3$ | the rate at which an infectious individual clinically recovered for SEIPR model (per time) |
| $\beta_4$ | the rate at which a clinically recovered individual fully recovered for SEIPR model (per time) |
| $\beta_5$ | transmission coefficient of susceptible individuals getting infected by infectious individual for SEIPR model (per time) |
| $\beta_6$ | transmission coefficient of susceptible individuals getting infected by clinically recovered individual for SEIPR model (per time) |

| | |
|---|---|
| $\beta_7$ | the rate at which a recovered individual loses its immunity for SEIPR model (per time) |
| $k_1$ | natural birth rate (per time) |
| $k_2$ | natural death rate (per time) |
| $k_3$ | death rate which is caused by disease (per time) |
| $E$ | number of infected individual during incubation period at time $t$ |
| $I$ | number of infectious individual at time $t$ |
| $N$ | total population |
| $P$ | number of clinically recovered individual (post-infectious virus shedding period) at time $t$ |
| $R$ | number of fully recovered individual at time $t$ |
| S | number of susceptible at time $t$ |

# CHAPTER 1

# INTRODUCTION

## 1.1 Motivation

Hand, foot and mouth disease (HFMD) is a common viral illness and mostly caused by viruses that belong to the enteroviruses group. The major causative agents of HFMD are coxsackievirus and human enterovirus 71 (EV-71) (Podin et al., 2006). The viruses are transmitted via fecal-oral route and can also spread through close contact with the patients, virus-contaminated surfaces, fomites and in respiratory droplets (Solomon et al., 2010). HFMD primarily affects infants and young children under age of 10 (Podin et al., 2006; SHD, 2018). Since 1997, the large outbreaks of human enteroviruses associated with hand, foot and mouth disease (HFMD) across the Asia-Pacific started to catch the public attention (McMinn, 2002; Podin et al., 2006). Countries such as Taiwan, China, Singapore, Malaysia, Vietnam, Mongolia and Brunei have created high number of infected cases and complicated death cases (Roy & Halder, 2010). Enterovirus 71 (EV 71) was first identified in California, USA, in 1969, which causes the HFMD with neurological and systemic complications (Solomon et al., 2010).

In Sarawak, series of HFMD outbreaks have occurred since 1997, affecting mostly children. This has raised the awareness of the public due to the fatalities cases reported. HFMD is endemic in Sarawak (SHD, 2018).