การศึกษาตัวแบบไม่เชิงเส้นของโรคพิษสุราเรื้อรังจากผลของการรณรงค์ผ่านสื่อในประเทศไทย

The Study of Nonlinear Model of The Effect of Awareness Program by Mass Media on Alcoholism in Thailand

ปิยดา วงศ์วิวัฒน์*

Piyada Wongwiwat*

สาขาวิชาสถิติประยุกต์, คณะวิทยาศาสตร์และเทคโนโลยี, มหาวิทยาลัยราชภัฏสวนสุนันทา

Applied Statitics Department, Faculty of science and Technology, Suan Sunundha Rajabhat University

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บทคัดย่อ

งานวิจัยนี้ได้พัฒนาตัวแบบไม่เชิงเส้นโดยใช้ตัวแบบ SS_MAM เพื่อศึกษาการแพร่กระจายของโรคพิษสุราเรื้อรังจากผลการรณรงค์ผ่านสื่อ ตัวแบบไม่เชิงเส้นนี้สร้างขึ้นโดยใช้วิธีแบบจำลองแบบไดนามิกมาตรฐาน ความคงที่ของตัวแบบถูกกำหนดโดยใช้เกณฑ์ตัดสินของ Routh-Hurwitz ผลการวิจัย พบว่า ตัวแบบไม่เชิงเส้นที่พัฒนาขึ้นเป็นไปตามเกณฑ์ ของ Routh-Hurwitz นอกจากนี้ผลการจำลองข้อมูลยังแสดงให้เห็นว่า การรณรงค์ผ่านสื่อเป็นวิธีที่มีประสิทธิภาพควบคุมการแพร่กระจายของโรคพิษสุราเรื้อรังในประเทศไทย

คำสำคัญ : ตัวแบบไม่เชิงเส้น การติดแอลกอฮอล์ สื่อ ค่าการแพร่กระจาย

Abstract

A nonlinear model of alcoholism is developed in this research by using the SS_MAM model to study the alcoholism transmission considering the effect of mass media. This nonlinear model was constructed by applying a standard dynamical modeling method. The stability of the model was determined by using Routh-Hurwitz criteria. The results were shown for supporting the new model. Also, the graphical representations were provided to qualitatively support the analytical results. The model implies that the mass media is an effective way to prevent and control the spread of alcoholism in Thailand.

Keywords : nonlinear model, alcoholism, media, basic reproductive number

*Corresponding author. E-mail : piyada.wo@ssru.ac.th

Introduction

Alcohol abuse is the leading cause of death of world population up to 3.3 million people died each year or around 5.9% of total death in the world. From World Health Organization (WHO, 2014), the figure of alcohol consumption in Thailand is the fifth in the world and the trend of this consumption has climbed up rapidly. In year 1989, the alcohol consumption in Thailand was 20.2 liter per person per year while it increased triple to 58.0 liters per person per year in year 2003. Many countries aware of alcohol drinking especially in the university life because the consumption of alcohol can be the Gateway Drugs leading to another drug addiction. (Steinberg, 1996)

Mass Media is a significant force in modern life that can be accessed from many sources; for example, Television, Internet, Radio, Billboard and Magazine etc. When people get information easily anywhere at any time, the mass media can play important role to form people personality and knowledge. Undoubtedly, the mass media is very effective tool to deliver the message to raise awareness of alcoholism and prevent the widespread and fetal effect of alcohol abuse. There were several researches such as Tchuenche *et al.* (2011), Greenhalgh *et al.* (2015) and Wongwiwat (2015) investigating of the role of media to infectious diseases and the results of studies showed that the mass media has a significant effect on disease control.

To study the dynamic of infectious diseases, the nonlinear model is very useful tool to apply. The analytical solution, numerical solution and simulation are ones of various mathematical methods used to analyze the harmful diseases without researching in the real environment that may infect the researchers, Swarnali and Samanta (2013), Bhunu (2012), Kaur *et al.* (2014), Zuo and Liu (2014) and Greenhalgh *et al.* (2015). Several researches mainly studied on the impact of awareness programs on and infectious diseases outbreak.

Thus, the new nonlinear model is applied to analyze the alcoholism transmission in order to understand the effect of mass media on the dynamic of the alcoholism in Thailand.

Methods

As the SS_MAM model, we consider effect of mass media the reduction of transmission level of this disease, then we separated susceptible class to susceptible class have no disease information and susceptible class have disease information. And both classes can be infective class. In this paper, we applied the structure of transfer diagram of model system from Swarnali and Samanta (2013), Kaur (2014) to suitable with the Alcoholism in Thailand. The population assumed that the human population is constant and divided into five compartments as follows: S, S_M, A and M represent the number of susceptible class, Alcoholism class, susceptible class acknowledge from content of media and the cumulative density of the mass media in that region at time t respectively. The transmission dynamics of the alcoholism in Thailand are described by the compartment diagram, Figure1.

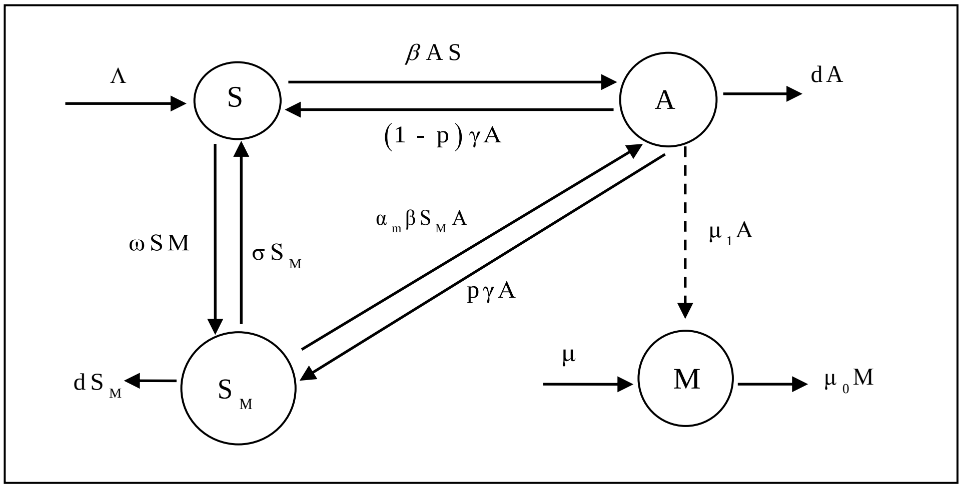


Figure1 The dynamics model of the alcoholism in Thailand

The transmission dynamics of the alcoholism in Thailand are described by the following systems of nonlinear ordinary differential equations:

$$\frac{dS}{dt} = \Lambda - [\beta A + \omega M + d]S + \sigma S_M + (1-p)\gamma A \quad (1)$$

$$\frac{dS_M}{dt} = \omega SM - (\alpha_m \beta A + \sigma + d)S_M + p\gamma A \quad (2)$$

$$\frac{dA}{dt} = (S + \alpha_m S_M)\beta A - (\gamma + d)A \quad (3)$$

$$\frac{dM}{dt} = \mu + \mu_1 A - \mu_0 M \quad (4)$$

Since the population of $N = S + S_M + A$; where Λ is the recruitment rate of human; β is the transmit rate of susceptible, d is the natural mortality rate, γ is the quitting rate of alcohol drinking σ is the return rate of quitted drinker to consume alcohol again. ω is the dissemination rate of awareness among susceptible due to media awareness program, α_m is decreasing rate of educated people becomes alcohol drinker, k is the rate constant corresponding to regular media coverage, μ is the rate constant corresponding to regular media coverage, μ_0 is the natural decay rate constant of media coverage/awareness programs, μ_1 is the rate constant influenced by number of infects, p is the probability of media accessibility and N is total population, respectively.

Step 1 : Equilibrium Analysis ; To begin with the disease free equilibrium, the endemic equilibrium and the basic reproductive number, respectively.

Step 2 : Stability Analysis ; To check the local stability of an equilibrium points is determine from the Jacobian matrix of the ordinary differential equation evaluated at E_0 and the endemic equilibrium points E_1 .

Step 3 :Numerical Simulation ; To demonstrated data to validate the performance of the nonlinear models by using Maple software.

Results and Discussion

1. Equilibrium Analysis

To begin with the disease free equilibrium, the endemic equilibrium and the basic reproductive number, respectively.

1.1) The disease free equilibrium (DEF) : The system has two equilibrium points; a disease free equilibrium point and an endemic equilibrium point.

$$E_0(S,S_M,V,I,M)=E_0\left(\frac{\mu_0\Lambda}{\omega\mu+\mu_0(\nu_1+d)},\frac{\omega\mu\mu_0\Lambda}{\mu_0(\omega\mu+\mu_0(\nu_1+d))(\nu_2+d)},\frac{\nu_1\mu_0\Lambda Q_5+\nu_2\omega\mu\mu_0\Lambda Q_2}{\beta\alpha_M\mu_0(1-\delta_M)\mu_0(\nu_2+d)Q_1Q_2},0,\frac{\mu}{\mu_0}\right)$$

1.2) The endemic equilibrium:

$$E_1\left(\frac{\mu_0\Lambda}{[\mu_0\beta(1-\delta_M)+\omega\mu_1]I^*+\omega\mu+\mu_0(\nu_1+d)},\frac{\omega\mu\mu_0\Lambda+\omega\mu_0\mu_1\Lambda I^*}{Q_3I^{2*}+Q_4I^*+Q_5},\frac{Q_6I^{2*}+Q_7I^*+Q_8}{(Q_1I^*+Q_2)(Q_3I^{2*}+Q_4I^*+Q_5)},I^*,\frac{\mu+\mu_1I^*}{\mu_0}\right)$$

1.3) The basic reproductive number:

The basic reproductive number is obtained by the next generation matrix. We start with $\frac{dX}{dt}=F(x)-V(x)$

where , F is the matrix of new infectious and V is the matrix of the transfers between the compartments in the infective equations. We obtained

$$F(x)=\begin{bmatrix}0\\0\\0\\\beta(1-\delta_M)(S+\alpha_MS_M)I+\beta_1VI\\0\end{bmatrix},\quad V(x)=\begin{bmatrix}[\beta(1-\delta_M)I+\lambda M+\nu_1+d]S-\Lambda\\ [\beta\alpha_M(1-\delta_M)I+\nu_2+d]S_M-\omega SM\\ (\beta_1I+\gamma_V+d)V-\nu_1S-\nu_2S_M\\ (\gamma+\gamma_M+d)I\\ \mu_0M-\mu-\mu_1I\end{bmatrix}.$$

Hence, basic reproductive number $(\Re_0)$ is $\Re_0 = \sqrt{\dfrac{\beta(1-\delta_M)S + \beta(1-\delta_M)\alpha_M S_M + \beta_1 V}{\gamma + \gamma_M + d}}$.

2. Stability Analysis

The local stability of an equilibrium points is determine from the Jacobain matrix of the ordinary differential equation evaluated at E_0.

$$J_0 = \begin{bmatrix} -(\omega M + \nu_1 + d) & 0 & 0 & -\beta(1-\delta_M)S & -\omega S \\ \omega M & -(\nu_2 + d) & 0 & -\beta\alpha_M(1-\delta_M)S_M & \omega S \\ \nu_1 & \nu_2 & -(\gamma_V + d) & -\beta_1 V & 0 \\ 0 & 0 & 0 & \beta(1-\delta_M)(S+\alpha_M S_M) + \beta_1 V - (\gamma+\gamma_M+d) & 0 \\ 0 & 0 & 0 & \mu_1 & -\mu_0 \end{bmatrix}_{E_0}.$$

The eigenvalues value of J_0 are obtained by solving $\det(J_0 - \lambda I)$. And we obtain the characteristic equation,

$$(-(\gamma_V + d) - \lambda)(-(\nu_2 + d) - \lambda)(-(\omega M + \nu_1 + d) - \lambda)(\beta(1-\delta_M)(S+\alpha_M S_M) + \beta_1 V - (\gamma + \gamma_M + d) - \lambda)(-\mu_0 - \lambda) = 0$$

where;

$$\lambda_1 = -(\gamma_V + d),\ \lambda_2 = -(\nu_2 + d),\ \lambda_3 = -(\omega M + \nu_1 + d),\ \lambda_4 = -(\gamma + \gamma_M + d) + \beta(1-\delta_M)(S+\alpha_M S_M) + \beta_1 V,\ \lambda_5 = -\mu_0$$

Next, we consider the stability of the endemic equilibrium points E_1, we examine the eigenvalue of Jacobian matrix at E_1, which is

$$J_1 = \begin{bmatrix} -B_1 & 0 & 0 & -B_6 & -\omega S \\ \omega M & -B_3 & 0 & -B_7 & \omega S \\ \nu_1 & \nu_2 & -B_5 & -\beta_1 V & 0 \\ B_2 & B_4 & \beta_1 I & -B_8 & 0 \\ 0 & 0 & 0 & \mu_1 & -\mu_0 \end{bmatrix}$$

The eigenvalues value of J_0 are obtained by solving $\det(J_0 - \lambda I)$. And we obtain the characteristic equation,

$$I^5 + C_1 I^4 + C_2 I^3 + C_3 I^2 + C_4 I + C_5 = 0$$

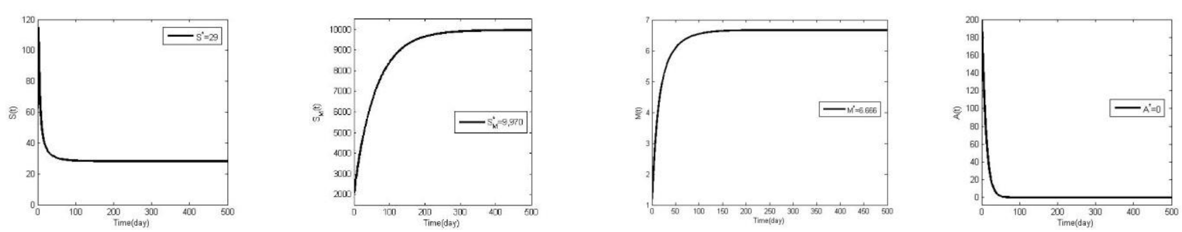
By Routh-Hurwitz criteria, equilibrium points are locally asymptotically stable if all conditions are satisfied:

1) $C_1C_2C_3 > C_3^2 + C_1^2C_4$

2) $(C_1C_4 - C_5)(C_1C_2C_3 - C_3^2 - C_1^2C_4) > C_5(C_1C_4 - C_3)^2 + C_1C_5^2$.

1.3 Numerical Simulation

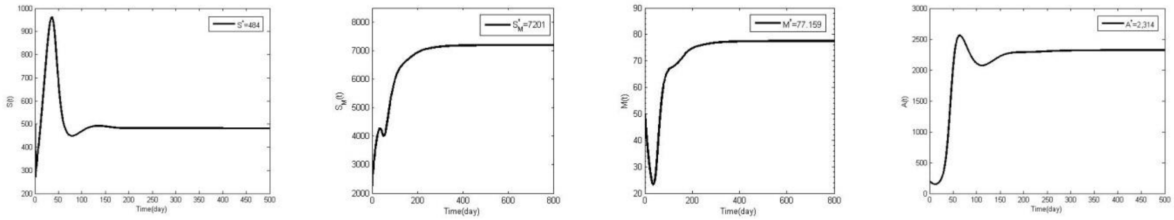
In this section, we present several scenarios using demonstrated data to validate the performance of the nonlinear models using the parameters obtained from literatures of Kaur et al. (2014). The parameters that were not available in literatures were estimated. The software used for computation is Maple. First, we consider stability of disease free state using set of parameter values of study the system of nonlinear ordinary differential equations (1-4). We found that, the eigenvalues corresponding to the equilibrium point E_0 and basic reproductive number are following: $\lambda_1 = -0.0166 < 0,\ \lambda_2 = -0.0299 < 0,\ \lambda_3 = -0.1002 < 0,\ \lambda_4 = -6.0176 < 0$, $\Re_0 = 0.2461 < 1$.
Since all eigenvalues corresponding to E_0 be negative, thus E_0 is locally asymptotically stable and basic reproductive number less than 1. Further, to illustrate the stability of endemic free state, shown that the results : $\lambda_1 = -0.000046,\ \lambda_2 = -0.005518,\ \lambda_3 = -0.001000,\ \lambda_4 = -0.082327,\ \lambda_5 = -0.142932$, $\Re_0 = 1.3183 > 1$. The same, all eigenvalues to be negative and basic reproductive number is greater than 1, the equilibrium state will be the endemic state, E_1. The disease free equilibrium (E_0) will be local asymptotically stable, as follows;



S $\qquad$ S_M $\qquad$ A $\qquad$ M

Figure 2 Time series of susceptible class, susceptible class acknowledge from content of media, alcoholism class and the cumulative density of the mass media, respectively.

From Figure 2, we found that the values of parameters are in the text and $\Re_0$ <1. We see that the solutions converge to disease free state. And we found that the values of parameters are in the text and $\Re_0$ >1. We see that the solutions converge to endemic free state following Figure 3.



S S_M A M

Figure 3 Time series of susceptible class, susceptible class acknowledge from content of media, alcoholism class and the cumulative density of the mass media, respectively.

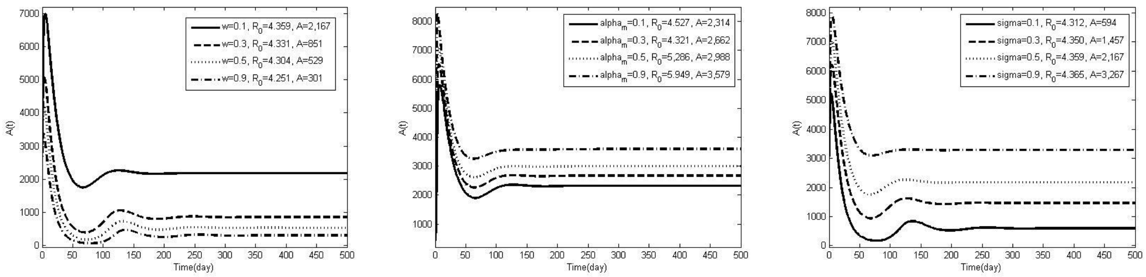


Figure 4 The effects of parameter ω ,σ and α_m respectively.

From Figure 4, the effects of parameter ω ,σ and α_m present that the more providing information to the high risk drinker is the less number of alcoholism reduces. While, when the awareness of threat of alcohol decreases, the number of alcoholism will increase a lot.

Table 1 The Basic reproduction number under effects of parameter ω ,σ and α_m respectively.

Parameters		A	$\Re_0$
ω	0.1	142	4.123
	0.3	47	3.729
	0.5	27	3.430
	0.9	15	3.000
σ	0.1	594	4.312
	0.3	1457	4.350
	0.5	2167	4.359
	0.9	3267	4.365
α_m	0.1	2314	4.527
	0.3	2662	4.921
	0.5	2988	5.286
	0.9	3579	5.949

The analytical result from this research told that if the rate of knowledge transferred to the alcohol risk takers by the awareness program increases, the index of alcoholism transmission and the number of alcohol addicts will reduce. Also, if we reduce the rate of return to addicts in the group of used-to-be addicted group, the index of alcoholism transmission and the number of alcohol addicts will decrease. On the other hands, if the rate of awareness program to alcohol risk takers is reduced, the index of alcoholism transmission and the number of alcohol addicts will be increased.

In conclusion, those parameters, the rate of knowledge transferred to the alcohol risk takers by the awareness program (ω), the rate of return to addicts in the group of used-to-be addicted group (σ) the rate of awareness program to alcohol risk takers (α_m) directly affect the dynamic of alcoholism. When the alcohol risk takers get a lot of information from the media $\Re_0 < 1$, there is no alcoholism transmission and vice versa.

Conclusions

The spread of Alcoholism by considering effect of mass media to the reduction of transmission level of this disease is analyzed. The study started from analytical solution, numerical solution and then simulation of the nonlinear model. The result are summarized in Figure 2 to Figure 4 and Table 1 by presenting the important values and the model system shown that the disease free equilibrium is stable until, the basic reproduction number, $\Re_0$ <1. The disease free equilibrium becomes unstable for $\Re_0$ >1, which leads to the existence of an endemic equilibrium,

$$\frac{dS}{dt} = \Lambda - [\beta A + \omega M + d]S + \sigma S_M + (1-p)\gamma A \qquad (1)$$

$$\frac{dS_M}{dt} = \omega SM - (\alpha_m \beta A + \sigma + d)S_M + p\gamma A \qquad (2)$$

$$\frac{dA}{dt} = (S + \alpha_m S_M)\beta A - (\gamma + d)A \qquad (3)$$

$$\frac{dM}{dt} = \mu + \mu_1 A - \mu_0 M \qquad (4)$$

Therefore, the model clearly shows that the mass media significantly causes the reduction in transmission and infection of alcoholism in Thailand.

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