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Proceedings of International Mathematical Sciences URL: https://dergipark.org.tr/tr/pub/pims Volume I Issue 2 (2019), Pages 60-68. A MATHEMATICAL MODEL OF A ZIKA VIRUS TRANSMISSION WITH IMPACT OF AWARENESS BY MED IA PUJI ANDAYANI UNIVERSITAS INTERNASIONAL SEMEN INDONESIA, PHONE:+6285736033960 Abstract. This paper has studied the transmission of Zika Virus with the impact of media. We analyzed the impact of the awareness programs on social media for the Zika Virus transmission model with saturated incidence rate.

The Beddington-De Angelis functional responses used to explain the inter- action between a suspected human and an infected human. The dynamical analysis identi?ed by computing the disease-free equilibrium(DFE) and en- demic equilibrium(END). The Basic Reproduction Number was identi?ed by Next Generation Matrix(NGM) method. Then the stability of DFE and END were analyzed locally by computing the determinant of Jacobian. The DFE was identi?ed as locally stable when the basic reproduction number was less than unity and was identi?ed as unstable otherwise. Otherwise, the END was identi?ed as existents when the basic reproduction number was greater than unity.

The Routh-Hurwitz Criterion showed that the END was locally stable under a speci?c condition. In the last, the stability of the equilibrium point was also identi?ed numerically depending on certain parameter values. 1. INTRODUCTION Zika virus is mostly transmitted through a bite from an Aides Aegypti mosquito during the day or night. Zika is also spread through sexual contact between an infected human and an uninfected human. In some cases, Zika is also passed on by pregnant women to her fetus which, causes a birth defect. No vaccine has been found to prevent Zika virus [1].

Based on [2], preventing Zika can be done by using insecticide-treated bed nets and mosquito repellent using a condom and prohibiting pregnant women to travel to the area with Zika outbreak [1]. Recently, most people change their mode of communication from face-to-face into online communication. Social media is one of the best forms of technology that responds to people's needs to communicate and share information online. Some common social media are Facebook, Twitter, Youtube, Whatsapp, and Instagram can be accessed easily by using smartphones and cellular applications [3]. 2010 Mathematics Subject Classi?cation. Primary: 34D20, 65P40, 37M05. Key words and phrases.

Zika Virus, dynamical analysis, social media, reproduction number, Next Generation Matrix, stability, Routh Hurwitz. c 2019 Proceedings of International Mathematical Sciences. 60 A MATHEMATICAL MODEL OF A ZIKA VIRUS TRANSMISSION WITH IMPACT OF AWARENESS BY MEDIA61 In a disease's epidemiology, social media has an important role to inform the disease's outbreak. Social media and TV advertising is one method to prevent transmission. Misra [4] has made a mathematical model to see the impact of TV advertising and social media on the dynamics of infectious diseases.

There are vulnerable populations that are vulnerable to infection as well as populations that often access information through social media. The Zika virus transmission can be informed through social media, then people can take preventive measures. Zika virus outbreak is expected to be controlled or does not spread into outer territory. The mathematical model of social media impact for the epidemiological disease has been researched by some authors. In 2014, the e?ects of media for in?uenza epidemic was discussed [5]. The SEIR model was constructed by including the me- dia function. The function f(I,p) was determined to reduce the transmission.

In 2018, a mathematical model of Zika virus transmission has been constructed and developed [6] [7]. In this paper, we study the impact of awareness programs on social media. The new parameter m, which becomes the basis of the exponential will be analyzed. We consider some of the trigger factors and preventive actions which are explained in a saturated model using Beddington DeAngelis incident rate. 2. MATHEMATICAL MODEL A modi?cation model for the Zika virus transmission with the saturated inci- dence rate and the impact of social media are as follows: dSh dt = ?h-ß1emI hShIh 1 +a1Sh +a2Ih- ß2ShIv 1 +a3Sh-µhSh, dIh dt = ß1emI hShIh 1 +a1Sh +a2Ih + ß2ShIv 1 +a3Sh- (? +µh)Ih, dRh dt = ?Ih-µhRh, dSv dt = ?v-ß3SvIh-µvSv, dIv dt = ß3SvIh-µvIv, (2.1) where Sh(t),Ih(t),Rh(t),Sv(t),Iv(t) stand for suspected human, infected human, recovered human, suspected mosquitoes, and infected mosquitoes respectively.

In this study, all of parameters are positive, where ?h denote the growth rate of hu- man, ?v denote the growth rate of mosquitoes,ß1 is the rate of direct transmission of human, ß2 is the rate of transmission from mosquitoes to human, and ß3 is the rate of transmission from human to mosquitoes. The per capita recovery rate of the infective population de?ned by gamma, a1,a2 the parameter that measure the inhibitory e?ect of human transmission, a3 the parameter that measure the inhibitory e?ect of mosquitoes bite, µh means the death rate of human, µv means the death rate of mosquitoes, respectively. Let (Sh,Ih,Rh,Sv,Iv) is the solution of the system, with positive initial value. Nh andNv are the total population of human and mosquitoes respectively, whereas Nh =Sh +Ih +Rh and Nv =Sv +Iv.

We assume all parameter and variables are 62 PUJI ANDAYANI positives. Then the solution of system are in the following : _ ? = (Sh,Ih,Rh,Sv,Iv)?R+5;Nh= ?h µh,Nv= ?v µv _ . (2.2) The derivation respect to time of the total population of the model 2.1 are : dNh dt = ?h-µhNh. (2.3) The solution of dN h dt +µhNh = ?h is ? h µ h-Ceµ ht. If Nh= ? h µ h , then ? h µ h = 0. If Nh > ? h µ h , then ? h µ h < 0. Then choose the initial value as follows : (1) Nh(0) = 0, then the solution is Nh(t) = ? h µ h (1-eµ ht), (2) Nh(0) = ? h µ h , the solution is Nh(t) = ? h µ h , (3) Nh(0)> 0, the solution is Nh(t) = ? h µ h (1-eµ ht) +Nh(0)eµ ht.

The total population of humans and mosquitoes are in the following : 0=Nh(t)=Nh(t) = ?h µh (1-eµ ht) +Nh(0)eµ ht, (2.4) and 0=Nv(t)=Nv(t) = ?v µv (1-eµ vt) +Nv(0)eµ vt. (2.5) In particular : Nh(t)= ?h µh,Nv(t)= ?v µv, when Nh(0)= ?h µh,Nv(0)= ?v µv. (2.6) Then the area n ? = (Sh,Ih,Rh,Sv,Iv)?R+5;Nh= ? h µ h,Nv= ? v µ v o is bounded. For Nh = Sh +Ih +Rh and Nv = Sv +Iv then we rewrite the model 2.1 into the following model: dNh dt = ?h-µhNh, dIh dt = _ ß1emI hIh 1 +a1(Nh-Ih-Rh) +a2Ih + ß2Iv 1 +a3(Nh-Ih-Rh) _ (Nh-Ih-Rh)- (? +µh)Ih dRh dt = ?Ih-µhRh, dNv dt = ?v-µvNv, dIv dt = ß3(Nv-Iv)Ih-µvIv. (2.7) 3.

MATHEMATICAL ANALYSIS Let the right hand equation of the system 2.7 by zero. Then we found two kinds of equilibrium points, namely disease free equilibrium (DFE) and endemic equilibrium (END) [10]. The disease free equilibrium of the system 2.7 is DFE = (Nh0,Ih0,Rh0,Nv0,Iv0) = _?h µh, 0, 0, ?v µv, 0 _ . (3.1) The DFE is always exists. A MATHEMATICAL MODEL OF A ZIKA VIRUS TRANSMISSION WITH IMPACT OF AWARENESS BY MEDIA63 Basic reproduction ratio is represent the natural compartmented for disease transmission model, established by the system of ordinary di?erential equation.

In this work, the basic reproduction ration compute by NGM as follows [10]. F = ? ? ß1Nh0 1 +a1Nh0 ß2Nh0 1 +a3Nh0 ß3Nv0 0 ? ?, V = _ ? +µh 0 0 µv _ . (3.2) F is the jacobian of infection matrix with respect to DFE, and V the jacobian matrix which decrease the infection. V -1 = ? ? ? 1 ? +µh 0 0 1 µv ? ? ?, F.V -1 = ? ? ? ? ß1Nh0 (1 +a1Nh0)(? +µh) ß2Nh0 (1 +a3Nh0)µv ß3Nv0 (? +µh) 0 ? ? ? ?. (3.3) Furthermore, the basic reproduction number is the largest number of eigenvalues of F.V -1. R0 = R01 + p R2 01 + 4R02 2 ; (3.4) where, R01 =ß1P1, R02 =ß2ß3P1P2Nv Nh . Lemma 1.

The disease-free equilibrium (DFE) of the system is local ly asymptoti- cal ly stable when R0 < 1 and Nh < µvs2d µvß1s2 +ß2ß3s1Nv , otherwise it is unstable. Proof. The Jacobian of model 2.7 is J(DFE) = ? ? ? ? ? ? -µh -J0 0 0 -J1 0 J0-µh-? 0 0 J1 0 ? -µh 0 0 0 -ß3Nv 0 -µv 0 0 ß3Nv 0 0 -µv ? ? ? ? ? ? . (3.5) where, J0 = ß1Nh s1 and J1 = ß2Nh s2 . The jacobian of DFE have ?ve eigen values, which are-µh,-µh and-µv. The two others are analyzed by identify the characteristic polynomials (3.6) as follows, P (?) =?2 +a1? +a0. (3.6) where, a1 = 1 s1 (-ß1Nh +s1d), a0 = 1 s1s2 (µvs1s2d-Nh(µvß1s2 +ß2ß3s1Nv)). 64 PUJI ANDAYANI The polynomial 3.6

have two negative real part eigen values, if a0 > 0 which is Nh < µvs2d µvß1s2 +ß2ß3s1Nv . _ Lemma 2. The endemic equilibrium (END) of the system is exist if R0 > 1 and a1d- (ß1e -mI h +a2µh)> 0 . Proof. The endemic equilibrium of the system 2.7 is END = (N * h,I * h,R * h,N * v,I * v). (3.7) Where, N * h = ?h µh, R * h = ? µhI * h, N * v = ?v µv, and I * v = ß3?h µv(ß3I * h +µv)I * h. The poin I * h is the positive root of the polynomial P (I * h) as follow. P (I * h) =b3I * h 3 +b2I * h 2 +b1I * h +b0, (3.8) with d =? +µh, ? =a1d-a2µh, and, b3 =a3µvß3d2(a1d- (ß1e -mI * h+a 2µh)), b2 = dµv[da3(µv?-(µhß3?1 + a2µh)) + ß3(µh?2(ß1e -mI * h- ?)- ß2Nv?) + ß1e -mI * ha3(µhß3Nh-a1d)], b1 =µhµv[ß2ß3NhNv?+µvd?2(ß1e -mI * h-?)+µhß3d?1?2+d?1(ß2ß3Nv-a3µvd)+ ß1e -mI * hNh?2(a3µvd-µhß3)], b0 =µ2 hµ2 v(?1?2(d-Nhß1e -mI * h)-?1ß2ß3NhNv µv). By calculus, the positiveness of constant b3,b2,b1 and b0 are identi?ed. Then the polynomial 3.8 have one positive roots if a1d- (ß1e -mI h+a 2µh)> 0.

_ The stability of endemic equilibrium(END) are identi?ed in the following Lemma. Lemma 3. The END is local ly stable if (N * v-I * v)< (µv +ß1I * h)(µhK2 +?K3) ß3µhK4 . Proof. The local stability of END is identi?ed by analyzing the following Jacobian. J(END) = ? ? ? ? ? ? -µh 0 0 0 0 K1 K2 K3 0 K4 0 ? -µh 0 0 0 0 0 -µv 0 0 -ß3(N * v-I * v) 0 ß3I * h -(ß3I * h-µv). ? ? ? ? ? ? . (3.9) where, K1 = ?1(1 +a2I * h 1 +a1(N * h-I * h-R * h) +a2I * h + ?2 1 1 +a3(N * h-I * h-R * h))> 0, K2 =-?1(1-1-mI * h I * h (N * h-I * h-R * h)- (a2-a1) 1 +a1(N * h-I * h-R * h) +a2I * h - ?2 1 +a3(N * h-I * h-R * h))- d< 0, K3 = -(1 +a2I * h)?1 1 +a1(N * h-I * h-R * h) +a2I * h - ?2 1 +a3(N * h-I * h-R * h) < 0, K4 = ß2(N * h-I * h-R * h) 1 +a3(N * h-I * h-R * h) > 0.

A MATHEMATICAL MODEL OF A ZIKA VIRUS TRANSMISSION WITH IMPACT OF AWARENESS BY MEDIA65 Clearly, the eigen value of matrix J(END) are-µv,-µh, and the three others are the roots of the following polynomial PEND(?). PEND(?) =?3 +c2?2 +c1?1 +c0, (3.10) where, c2 =ß3I * h +μv +μh-K2 > 0, c1 =μvμh-K2(μv +μh) +ß3I * h(μh-K2) +ß3K4(I * v-N * v)-?K3 > 0, c0 =-ß3μhK4(N * v-I * v)- (μv +ß3I * h)(μhK2 +?K3). By using Routh-Hurwitz Criterion [8] the polynomialPEND(?) have three negative real parts eigenvalue since c2 > 0, and c1c2-c0 > 0. Then, the parameter c0 > 0 when (N * v-I * v) < (μvß1I * h)(μhK2 +?K3) ß3μhK4 .

Hence, the the END is locally stable under condition (N * v-I * v)< (μv +ß1I * h)(μhK2 +?K3) ß3μhK4 . _ 4. NUMERICAL RESULT AND DISCUSSIO N In this section, we describe the numerical simulation of the model 2.7 to verify the analytical result. Under some certain condition which satis?es the quali?ca- tion of basic reproduction number, the trajectory of the system 2.7 are identi?ed. The sensitivity analysis also needs to analyze the most sensitive parameter in the model. For simulation, we choose some parameter value which satis?es the quali- ?cation condition. The following table provides the parameter description and the parameter value which is used in the numerical simulation. Tabl e 1.

The parameter probability by [6] [11] Parameter Probability(value) ?h μhNh (person per-day) μh 1 lifetime = 1 65x365 = 0.00004215 (per-day) a1 0=a1= 1 (person x day) ß1 0=ß1= 1 (person x day) ß2 0=ß2= 1 (person x day) ß3 0=ß3= 1 (mosquitoes x day) ? 0=?= 1,? = 1 recoverytime = 1 7 = 0.1428 (per-day) ?v μvNv (mosquitoes per-day) μv 1 lifetime = 1 14 = 0.0714 (per-day) Then take the parameter values as follow : ?h = 0.004215,μh = 0.00004215,μv = 0.0714,ß1 = 0.0001,ß2 = 0.002,ß3 = 0.0001,? = 0.1428, ?v = 71.4,m = 2,a1 = 0.95,a2 = 0.1, and a3 = 0.96. Under that parameter value than we have the fol- lowing result.

The ?gure 1a and ?gure 1b tell us the trajectories of the system 2.7 when the basic reproduction number is less than unity. The solution of the system will tends to the suspect human and mosquitoes which means the infected population is ex- tinct. Then the system is free from disease along certain times. 66 PUJI ANDAYANI (a) Simulation 1 (b) Simulation 2 Figure 1. Numerical Result of model (2.7) when R0 < 1, (a) Simulation when t = 4000 (b) Simulation when t = 18000 The sensitivity analysis was performed to determine the relative importance of model parameters of disease transmission. Choose the parameter value, μv = 0.0714,μh = 0.00004215, ?h = 10, ?v = 20,ß1 = 0.02,ß2 = 0.0007,ß3 = 0.01,a1 = 0.35,a3 = 0.95,? = 0.1428. Based on mathematical computation and normaliza- tion the sensitivity index of R0, we have the following result (Table 1). Tabl e 2.

Table of sensitivity index for each parameter of the system 2.7 Parameter Sensitivity Index Interpretation (Increasing or decreasing) Rank ?h 0.00000621 ?h by 10%, R0 increasing by 0.000621% 7 μh -0.000213693 μh by 10%, R0 decreasing by 0.021% 6 a1 -0.40627261 a1 by 10%, R0 decreasing by 40.6% 4 a2 0 a2 by 10%, R0 by increasing 0% 8 a3 -0.296859936 a3 by 10%, R0 decreasing by 29.6% 3 ß1 0.4062775 ß1 by 10%, R0 increasing by 40.6% 4 ß2 0.296861253 ß2 by 10%, R0 increasing by 29.6% 5 ß3 0.296861253 ß3 by 10%, R0 increasing by 29.6% 5 ? -0.7029312644 ? by 10%, R0 decreasing by 70.2% 1 ?v 0.4975303648 ?v by 10%, R0 increasing by 49% 3 μv -0.5937225055 μv by 10%, R0 decreasing by 59.3% 2 According to table 2, we can see that the most sensitive parameter of the model x is the recovery rate of the infection population (?).

The second one is the death rate of mosquitoes (μv) and the third one is the parameter that measures the inhibitory e?ect of mosquitoes bite (a3). The solution we can do to prohibit the problem of Zika virus, beginning with the pursuit of healing of infected humans, such as con- ducting treatment and providing vaccines. Then reduce the mosquito population by maintaining environmental cleanliness and prevent mosquito-spread according to government recommendations. Additionally, by taking precautions to be free from Aedes Aegyepti mosquito bites.

Conversely, the least sensitive parameter is the parameter that measures the inhibitory e?ect of human transmission (a2). So A MATHEMATICAL MODEL OF A ZIKA VIRUS TRANSMISSION WITH IMPACT OF AWARENESS BY MEDIA67 for further model development, these parameters a2 do not need to be used. 5. CONCLUSION In this paper, we have discussed the interaction among human which suspected, infected, recovered from Zika virus and mosquitoes which infected and suspected Zika. The parameter of social media is also used to see the impact on that model.

To see the e?ects of social media on the transmission of Zika virus, mathematical models using systems with ?ve nonlinear di?erential equations were constructed. The boundedness problem of the system is analyzed and proved by ordinary math- ematical calculations. By letting the right-hand side of the system by zero, the two types of equilibrium points were obtained with a certain existing condition, namely disease-free and endemic. The basic reproduction numbers are the basis for the conditions of stability and the existence of equilibrium points, were found by using the Next Generation Matrix (NGM).

The dynamical analysis has been solved out by using supporting theorems such as Descartes and Routh-Hurwitz criteria. Based on the analytical result, the disease-free equilibrium points are locally asymptot- ically stable when the basic reproduction number was less than unity. Moreover, the endemic equilibrium point exists and locally stable when the basic reproduction number is more than unity and satis?ed the certain parameter requirement.

The sensitivity analysis is also analyzed to identify the sensitivity of each parameter of the model. Then, the most sensitive parameter of the model 2.7 is the recovery rate of the infective population (?). Conversely, the least sensitive parameter is the inhibitory e?ect of human transmission (a2). It becomes a recommendation for the next model development, the parameters a2 is no need to be used. Numerical simulations of the dynamic behavior of equilibrium points were also presented to complete the analytical results. Then generally it can be concluded that social media a?ect reducing the spread of the Zika virus. 6.

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