

Mathematical Modelling and The Transmission Dynamic of The Ebola Disease with Hospitalised Treatment

Ali Inalegwu Michael¹, Washachi Dekera Jacob², Aliyu Garga Dzarma²

¹Department Of Mathematics and Statistics Federal University Wukari

²Department Of Mathematics Nigerian Army University Biu

Corresponding Author's Email: washachidekera@naub.edu.ng

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ABSTRACT

The model is governed by a system of five ordinary differential equations namely: five compartments namely: the susceptible (S), Exposed (E), Infected (I), Hospitalized (H), and Recovery (R). The model was analyzed to find the global stability, reproduction number, bifurcation, endemic equilibrium, and disease-free equilibrium. The analysis's findings show that the bifurcation displays reverse bifurcation. There is now global asymptotic stability in the system. Based on numerical simulations of the model, it was found that the first week of the outbreak was when Ebola was most common. But as safety precautions were put in place, it gradually decreased. It is significant to remember that in order to avoid a relapse into the original high levels, treatment is required. The contaminated compartment remained high throughout the first five weeks of the outbreak, but with the right therapy, it began to diminish. Due to drug experimenting, the hospitalized compartment saw a large number of patients during the first week. Nonetheless, it kept declining with the right medication administration. The recovery section illustrates that prompt identification and appropriate care are essential for each person to recover from Ebola.

Keywords: Ebola, backward bifurcation, proper treatment, Global Stability, quick detection

1.0 INTRODUCTION

The Ebola virus, which causes the sickness, is an acute, contagious illness that is characterized by fever and severe internal bleeding. It is contracted by coming into touch with infected bodily fluids. In what is now the Democratic Republic of the Congo, the Ebola River was the site of the first recorded ebolavirus discovery in 1976. Since then, ebolaviruses have sporadically surfaced and infected individuals throughout a number of African nations (Manuel *et al.*, 2020). Even though there have since been outbreaks in other places, the Ebola virus is called after the place where it was originally discovered. The Zaire ebolavirus is one of the ebola types. The Sudan ebolavirus, also referred to as the Zaire ebolavirus, is the cause of Ebola virus disease (EVD). Bundibugyo ebolavirus, also known as Tai Forest ebolavirus, Tai Forest virus disease (TAFV), and Sudan virus, also known as Sudan ebolavirus, causes Sudan viral disease (SVD). BDBV, or Bundibugyo viral disease, is caused by the Bundibugyo ebolavirus, sometimes referred to as Bundibugyo virus (Jean-Philippe, 2014). Hemorrhagic fever viruses are the source of the disease Ebola. The virus known as Ebola spreads through direct contact with bodily fluids such as blood, saliva, sweat, tears, mucus, vomit, feces, breast milk, urine, and semen from infected individuals. It causes severe inflammation and tissue destruction throughout the body. Eight to ten days after an individual contracts the virus, symptoms of EVD typically start to appear. A person cannot contract the

virus from another unless they show symptoms (Stephen 2017, Cleveclinic, 2023).

Inmazeb TM and EbangaTM are two monoclonal antibody therapeutics for the Ebola virus sickness. Similar to the body's own antibodies, monoclonal antibodies aid in warding off infection as the body fortifies itself. Ebanga is a single monoclonal antibody, whereas Inmazeb is a mixture of three monoclonal antibodies. These therapies have only been investigated for ebolavirus infections in Zaire (CDC, 2016). When caring for someone who has Ebola, using protective gear (masks, goggles, apron, and gloves) is part of the prevention of the disease. Even if you are wearing gloves, avoid handling any bodily fluids and wash your hands after touching them. Until testing show that the ebolavirus is not present in the semen, use condoms or refrain from having intercourse. Stay away from anything that has come into contact with bodily fluids that are contaminated. Semen should not be handled until testing has determined that it is virus-free. If you must handle an Ebola victim's body, do so with caution or use protective gear.

This also applies to funeral traditions. Steer clear of bodily fluids and tissues from animals—alive or dead—that may be infected with Ebola. Wild animal meat, or bush meat, should not be consumed. The Sudan ebolavirus, which causes Ebola, was the source of the 2022–2023 Uganda Ebola outbreak, which struck the

country's Western and Central Regions from September 20, 2022, to January 10, 2023. There were over 160 cases of infection, 77 of which resulted in death (World Health Organization, 2023). The Centers for Disease Control (CDC, 2016) reported that 11,310 deaths and 28,616 cases of EVD were recorded in Guinea, Liberia, and Sierra Leone. When the outbreak extended outside of these three countries, there were a further 36 cases and 15 deaths (World Health Organization, 2023, CDC, 2016, Rafiq *et al.*, 2020). On July 23, 2014, the first case of EVD was verified in Lagos, Nigeria, and it quickly spread to 19 other laboratory-confirmed cases. The EVD cases were not just found in Lagos State; two verified instances were found in Rivers State, with one of the cases ending in death. Quick public health efforts were enough to stop this feared sickness from spreading across the entire nation. The 2014 Nigerian Ebola crisis is described in this exploratory formative study. There have been 20 cases, 8 fatalities, and 12 recoveries in Nigeria overall (Akaninyene *et al.*, 2018).

1.1 Objective of the Study

The objectives of the study are to:

- Modify models by Rafiq *et al.*, (2020) by including hospitalized compartment.
- Obtain both the disease-free and endemic equilibrium of the Ebola
- Derive the reproduction number for the Ebola.
- Carried out local stability of the Ebola virus using the bifurcation method.
- Carried out the global stability of the Ebola virus.
- Carried out the numerical simulation of the Ebola virus.

2.0 MATHEMATICAL FORMULATION

In this paper we divided the model into five compartments namely: the susceptible (S), Exposed (E), Infected (I), Hospitalized (H), and Recovery (R). It is believed that immunity is not lifelong. It is also considered that people can recover without medical intervention and, lastly, that hospitalized patients have a better chance of recovering. The recruitment into susceptible is at the rate Λ , the susceptible recruitment reduces at the rates $\left(\mu + \frac{\beta I}{N}\right)S$ and increase at the rate

α . The parameter β is the contact rate of the disease. Each compartment suffers the natural death at the rate μ . The exposed compartment $E(t)$ rise as a result of the infection's passage into the compartment and fall as a result of its movement out of the compartment at the rates $(\mu + \varepsilon + \tau)$. The parameter ε is the progression into infected compartment and τ is the movement from exposed to hospitalized compartments. The infected compartment $I(t)$ increase at the rate ε and suffer the induced death at the rate ω , reduces at the rate $(q + \delta)$ where q is the natural recovery and δ is the rate at which people move to the hospital. The hospitalized compartment $H(t)$ increase at the rate $(\delta + \tau)$ and reduces due to the natural death rate μ and induced death rate ω and recovered due to treatment γ . The recovery compartment $R(t)$ increases due to the natural recovered and recovery due to treatment at the rate q and γ respectively and reduces at the rate $(\alpha + \mu)$. where α is the loss of immunity.

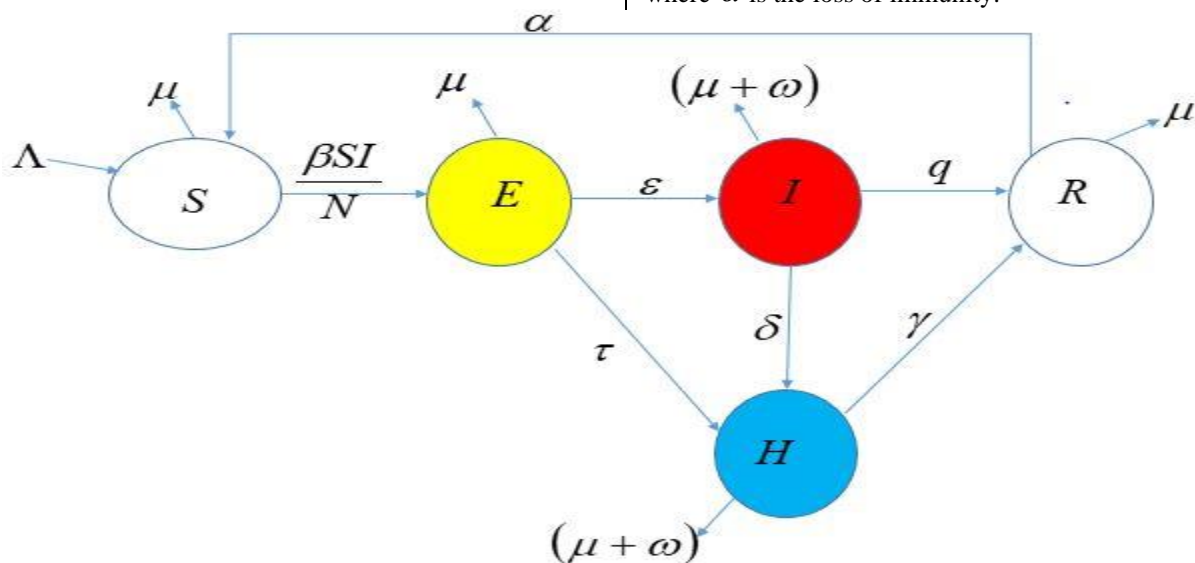


Figure 1 Schematic Diagram of the Model

2.1 Equations of the Model

$$\left. \begin{aligned} \frac{dS}{dt} &= \Lambda + \alpha R - \mu S - \frac{\beta SI}{N} \\ \frac{dE}{dt} &= \frac{\beta SI}{N} - A_1 E \\ \frac{dI}{dt} &= \varepsilon E - A_2 I \\ \frac{dH}{dt} &= \tau E + \delta I - A_3 H \\ \frac{dR}{dt} &= qI + \gamma H - A_4 R \end{aligned} \right\} \quad (1)$$

$$\left. \begin{aligned} A_1 &= (\tau + \varepsilon + \mu) \\ A_2 &= (\mu + \omega + \delta + q) \\ A_3 &= (\mu + \omega + \gamma) \\ A_4 &= (\mu + \alpha) \end{aligned} \right\} \quad (2)$$

With initial conditions; $S(0) = S_0, E(0) = E_0, I(0) = I_0, H(0) = H_0, R(0) = R_0$.

Table:1 Variables and parameters of the model

Parameters	Description	Values	Ref.
β	Contact rate	0.27	Abah <i>Etal</i> , (2023)
ω	Induced death rate	0.03	Rivers <i>etal</i> , (2014)
μ	Natural death rate	0.02	Rivers <i>etal</i> , (2014)
N	Total population	2 138 500	Estimated
γ	Recovery due to treatment	0.0629	Edwarda <i>etal.</i> , (2017)
δ	Movement of Infected to the Hospital	0.9	Washachi <i>etal.</i> , (2022)
q	Natural recovery	0.03	Estimated
α	Loss of immunity	0.73	Abah <i>etal.</i> , (2023)
Λ	Recruitment	10^6 /Year	Rivers <i>etal</i> , (2014)
τ	Progression from exposed to Hospitalized		Estimated

3.0 MODEL ANALYSIS

The following findings, which we derive in this part, ensure that the Ebola disease, which is controlled by system (1), is both mathematically and epidemiologically well posed in a workable Region determined by:

$$S_0 = \left\{ \{S, E, I, H, R\} \in R_+^5 \mid S > 0, E \geq 0, I \geq 0, H \geq 0, R \geq 0, N_{(t)} \leq \frac{\Lambda}{\mu} + \left(\mu_0 - \frac{\Lambda}{N} \right) e^{\mu t} \right\}$$

3.1 Disease Free and Endemic Equilibrium Points of the Ebola Virus Model

We find the equilibrium points by setting the right-hand side of the system (1.0) to zero as follows:

$$\left. \begin{aligned} \Lambda + \alpha R - \mu S - \frac{\beta SI}{N} &= 0 \\ \frac{\beta SI}{N} - A_1 E &= 0 \\ \varepsilon E - A_2 I &= 0 \\ \tau E + \delta I - A_3 H &= 0 \\ qI + \gamma H - A_4 R &= 0 \end{aligned} \right\} \quad (3)$$

When there is no disease in the population

($E(t) = I(t) = H(t) = 0$), the disease-free equilibrium (DFE) point of the Ebola virus model (1.0) exist and is given

$$\text{by } E_0 = (S_0, E_0, I_0, H_0, R_0) = \left\{ \frac{\Lambda}{\mu}, 0, 0, 0, 0 \right\}$$

To compute the endemic equilibrium point (EEP), from equation (1) and (2) we have:

$$\begin{aligned} S &= \frac{-N\Lambda A_1 A_2 A_3 A_4}{\alpha^2 \beta \gamma I A_2 + \alpha \beta \varepsilon^2 I A_3 + \alpha \beta \gamma \delta \varepsilon I - N\mu A_1 A_2 A_3 A_4 - \beta I A_1 A_2 A_3 A_4} \\ E &= \frac{-N\Lambda \mu A_1 A_2^2 A_3^2 A_4^2}{(\gamma A_2 \alpha^2 + A_3 \alpha \varepsilon^2 + \gamma \delta \alpha \varepsilon - A_1 A_2 A_3 A_4) (\beta \gamma I A_2 \alpha^2 - A_3 \alpha \alpha^2 + \beta \gamma \delta I \alpha \varepsilon + \beta - N\mu A_1 A_2 A_3 A_4 - \beta I A_1 A_2 A_3 A_4) - N\mu A_1 A_2 A_3 A_4} \\ I &= \frac{\alpha^2 \beta \gamma A_2 + \alpha \beta \varepsilon^2 A_3 - \beta A A_1 A_2 A_3 A_4 + \alpha \gamma \delta \varepsilon}{-N\mu A_1 A_2 A_3 A_4} \\ H &= \frac{-\Lambda A_4 (\beta \delta \varepsilon I + \alpha \beta I A_2)}{\beta \gamma I A A_2 \alpha^2 + \beta I A_3 \alpha \varepsilon^2 + \beta \gamma \delta I \alpha \varepsilon - N\mu A_1 A_2 A_3 A_4 - \beta I A A_1 A_2 A_3 A_4} \\ R &= \frac{-\Lambda \beta I (A_2 \varepsilon^2 + \gamma \delta \varepsilon + \alpha \gamma A_2)}{\beta \gamma I A_2 \alpha^2 + \beta I A_3 \alpha \varepsilon^2 + \beta \gamma \delta I \alpha \varepsilon - N\mu A_1 A_2 A_3 A_4 - \beta I A A_1 A_2 A_3 A_4} \end{aligned} \quad (4)$$

3.2 Basic Reproduction Number

The predicted number of secondary cases that a typical infective individual would produce in a whole susceptible population is the basic reproduction number, indicated by R_0 .

Let $F(x)$ be the rate at which new infections emerge in the compartment. $V_I^*(x)$ be the pace at which people are moved out of the cubicle (Van den Driessche & Watmough, 2002).

It can be calculated as $R_0 = \eta(FV^{-1})$ where

$$F = \begin{pmatrix} 0 & \beta & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \text{ and } V = \begin{pmatrix} A_1 & 0 & 0 \\ -\varepsilon & A_2 & 0 \\ -\tau & -\delta & A_3 \end{pmatrix}$$

$$\text{and } FV^{-1} = \begin{pmatrix} \frac{\beta \varepsilon}{A_1 A_2} & \frac{\beta}{A_2} & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Hence the reproduction number for the Ebola Virus is the dominant Eigen value, thus $R_{0M} = \eta(FV^{-1})$, where ρ is the spectral radius such that

$$\therefore R_0 = \frac{\beta\varepsilon}{A_1A_2} \quad (5)$$

3.3 Local Stability of the Disease-Free Equilibrium of the Ebola virus Model using Bifurcation method Stability Analysis using Bifurcation Analysis

The centre manifold theory can be used to analyse the stability nearer the DFE (E^0) and $R_0 = 1$. Therefore, from

$$R_0 = \frac{\beta\varepsilon}{A_1A_2}, \text{ let } \beta = \theta \text{ be the bifurcation parameter and } R_0 = 1 \text{ be the bifurcation point and making } \theta \text{ subject of}$$

the formula we have

The stability nearer the DFE (E^0) and $R_0 = 1$ can be analyzed using the center manifold theory. As a result, starting with let $\beta = \theta$ be the bifurcation parameter and $R_0 = 1$ as the bifurcation point, we may formulate the formula that

$$\text{follows. } \theta = \frac{A_1A_2}{\varepsilon}. \quad \text{Let } S = x_1, E = x_2, I = x_3, H = x_4, R = x_5 \quad (6)$$

Substituting (6) into (1) we have

$$\left. \begin{aligned} \frac{dx_1}{dt} &= \Lambda + \alpha x_5 - \frac{\beta x_1 x_3}{N} - \mu x_1 \\ \frac{dx_2}{dt} &= \frac{\beta x_1 x_3}{N} - A_1 x_2 \\ \frac{dx_3}{dt} &= \varepsilon x_2 - A_2 x_3 \\ \frac{dx_4}{dt} &= \tau x_2 + \delta x_3 - A_3 x_4 \\ \frac{dx_5}{dt} &= q x_3 + \gamma x_4 - A_4 x_5 \end{aligned} \right\} \quad (7)$$

Differentiating (7) at disease free equilibrium we have

$$\begin{pmatrix} -\mu & 0 & -\beta & 0 & \alpha \\ 0 & -A_1 & \beta & 0 & 0 \\ 0 & \varepsilon & -A_2 & 0 & 0 \\ 0 & \tau & \delta & -A_3 & 0 \\ 0 & 0 & \varepsilon & \tau & -A_4 \end{pmatrix} \quad (8)$$

Evaluating (8) for right and left eigenvector we have

$$\left. \begin{aligned} w_1 &= \frac{\alpha}{\mu} \left[\frac{\varepsilon^2 w_2}{A_4 A_2} + \frac{\gamma}{A_4} \left(\frac{\tau \theta \varepsilon}{A_1 A_2 A_3} + \frac{\delta \varepsilon}{A_3 A_2} \right) w_2 \right] \frac{\theta \varepsilon}{\mu A_2} \left[\frac{\beta \varepsilon}{A_1 A_2} \right] w_2 \\ w_2 &= \left[\frac{\beta \varepsilon}{A_1 A_2} \right] w_2 \\ w_3 &= \frac{\varepsilon w_2}{A_2} \\ w_4 &= \left(\frac{\tau \theta \varepsilon}{A_1 A_2 A_3} + \frac{\delta \varepsilon}{A_3 A_2} \right) w_2 \\ w_5 &= \left[\frac{\varepsilon^2}{A_4 A_2} + \frac{\gamma}{A_4} \left(\frac{\tau \theta \varepsilon}{A_1 A_2 A_3} + \frac{\delta \varepsilon}{A_3 A_2} \right) \right] w_2 \end{aligned} \right\} \quad (9)$$

$$\left. \begin{aligned} v_1 &= 0 \\ v_2 &= \frac{\theta \varepsilon}{A_1 A_2} v_2 \\ v_3 &= \frac{\theta v_2}{A_2} \\ v_4 &= 0 \\ v_5 &= 0 \end{aligned} \right\} \quad (10)$$

We must determine the sign of \mathbf{a} and \mathbf{b} in order to establish the criteria for the existence of backward bifurcation after computing the right and left eigenvalues, as shown in the following theorem.

Theorem 2. Consider the following general system of ordinary differential equations with a parameter θ .

$$\frac{dx}{dt} = f(x, \theta), f: \mathbb{R}^n \times \mathbb{R} \rightarrow \mathbb{R} \text{ and}$$

$$f \in C^2(\mathbb{R}^n \times \mathbb{R})$$

(11)

where θ is an equilibrium point of the system, that is, $f(0, \theta) \equiv 0 \forall \theta$ and

i. $A = D_x f(0, 0) = \left[\frac{\partial f_i}{\partial x_i}(0, 0) \right]$ is the

linearization matrix of the system around the equilibrium with θ evaluated at 0.

ii. Zero is a simple eigenvalue of A and all other eigenvalue A have negative real parts.

iii. Matrix A has a right eigenvector w and a left eigenvector v corresponding to the zero eigenvalues.

Let f_K be the K th component of f and

$$a = \sum_{k,i,j=1}^n v_k w_i w_j \frac{\partial^2 f_k}{\partial x_i \partial x_j}(0, 0) \quad (12)$$

and

$$b = \sum_{k,i=1}^n v_k w_i \frac{\partial^2 f_k}{\partial x_i \partial \theta}(0, 0)$$

(13)

The local dynamics of system (7) around equilibrium are totally governed by the signs of a and b . Consequently, the subsequent circumstances apply:

i. $a > 0$, $b > 0$, when when $\theta < 0$, with $|\theta| \ll 1$, 0 is locally asymptotically stable, and a positive unstable

equilibrium exists; when $0 < \theta \ll 1$, There is a negative, locally asymptotically stable equilibrium; the equilibrium is unstable.

ii. $a < 0$, $b < 0$, When $\theta < 0$, with $|\theta| \ll 1$, 0 is unstable; that is, when $0 < \theta \ll 1$, there is a positive unstable equilibrium and the equilibrium is locally asymptotically stable.

iii. $a > 0$, $b < 0$, When $\theta < 0$, with $|\theta| \ll 1$, 0 is unstable and a positively unstable equilibrium emerges; when $0 < \theta \ll 1$, 0 is stable and a locally asymptotically stable negative equilibrium arises.

iv. $a < 0$, $b > 0$, when θ transforms its stability from stable to unstable when it goes from negative to positive. In turn, a negative unstable equilibrium turns positive and asymptotically stable locally. Especially if $a > 0$, and $b > 0$, there is a backward split at $\theta = 0$: (Olaniyi & Obabiyi 2014, Washachi, *et al.*, 2023).

Computation of a and b

$v_1 = v_4 = v_5 = 0$ for $k = 1, 5$; The only partial derivatives that deviate from zero are $k=2, 3$. Evaluating equation (7) we have

$$\frac{\partial^2 f_2}{\partial x_1 x_3} = \frac{\theta \mu}{\Lambda}$$

(14)

Substituting equation (9), (10) and (14) into (12) we have

$$a = \frac{\theta \varepsilon}{A_1 A_2} v_2 w_2^2 > 0$$

Evaluating equation (7), we have

$$\frac{\partial^2 f_2}{\partial \theta \partial x_3} = \frac{x_1}{N}$$

(15)

Substituting equation (9), (10) and (15) into (13) we have

$$b = v_2 w_2 > 0$$

Given that $a > 0$ and $b > 0$, the first requirement of theorem 2 is satisfied. As a result, the Ebola virus model shows a bifurcation in reverse.

3.4 Global stability of Ebola Virus model

For global stability of the DFE, the technique used by Castillo-Chavez et al. [16] was employed. The model is rewritten as follows:

$$\left. \begin{aligned} \frac{dX}{dt} &= K(X, Z) \\ \frac{dZ}{dt} &= G(X, Z), \quad G(X, 0) = 0 \end{aligned} \right\}$$

(16)

where $X \in \mathbb{R}^2$ and $X = \{S, R\}$ denotes the number of uninfected individuals and $Z \in \mathbb{R}^2$ where $Z = \{E, I, H\}$ denotes the number of infected individuals. $E^0 = \left\{ \frac{\Lambda}{\mu}, 0, 0, 0, 0 \right\}$ denotes the disease-free equilibrium point of this system, where,

$$x^* = \begin{pmatrix} \Lambda \\ \mu \end{pmatrix}$$

(17)

Condition (16) may be met to guarantee global asymptotic stability

(H_1): For $\frac{dx}{dt} = k(x, 0)$, x^* is globally asymptotic stable.

(H_2): For $G(X, Z) = AZ - \hat{G}(X, Z)$, $\hat{G}(X, Z) \geq 0$ $\forall (x, z) \in \Gamma$ where $A = D^G(x^*, 0)$ is an m matrix and Γ is the region where the model has biological meaning.

Theorem 1. If the system (1) satisfies condition (16), then the fixed point $E^0 = \left\{ \frac{\Lambda}{\mu}, 0, 0, 0, 0 \right\}$ is a globally asymptotically stable equilibrium of the system (1) provided that $R_0 < 1$ and the conditions (H_1) and (H_2) are satisfied:

Proof

Consider $K(X, 0) = [A - \mu S]$ and $G(X, Z)$ and $G(X, Z) = AZ - \hat{G}(X, Z)$

$$A = \begin{pmatrix} -A_1 & \frac{\beta S}{N} & 0 \\ \varepsilon & -A_2 & 0 \\ \tau & \delta & -A_3 \end{pmatrix}$$

(18)

And

$$Z = \begin{bmatrix} E \\ I \\ H \end{bmatrix}$$

(19)

$$G(X, Z) = \begin{vmatrix} \frac{\beta SI}{N} - A_1 E \\ \varepsilon E - A_2 I \\ \tau E + \delta I - A_3 H \end{vmatrix}$$

(20)

Given

$$\hat{G}(X, Z) = AZ - G(X, Z)$$

(21)

Substituting equations (18), (19), and (20) into (21) we have

$$\hat{G}(X, Z) = \begin{pmatrix} -A_1 & \frac{\beta S}{N} & 0 \\ \varepsilon & -A_2 & 0 \\ \tau & \delta & -A_3 \end{pmatrix} \begin{bmatrix} E \\ I \\ H \end{bmatrix} - \begin{bmatrix} \frac{\beta SI}{N} - A_1 E \\ \varepsilon E - A_2 I \\ \tau E + \delta I - A_3 H \end{bmatrix} \geq \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

(22)

Since all the conditions are satisfied, $\hat{G}(X, Z) \geq 0$, the DFE, E^0 is globally asymptotically stable.

4.1 Numerical simulation

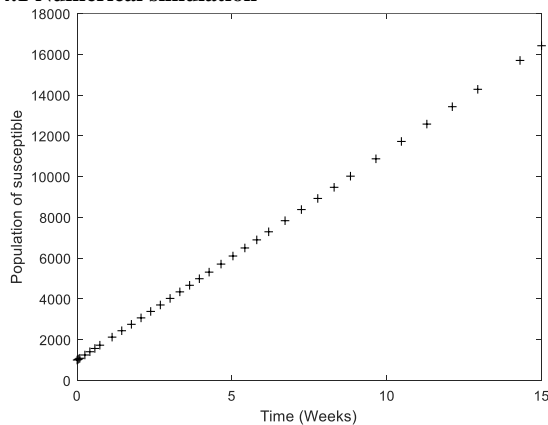


Figure 2: Diagram showing the dynamics of Susceptible Humans.

The line in Figure 2 shows that, as of right now, there is no ebola in the population and that deaths are due to natural causes rather than the illness.

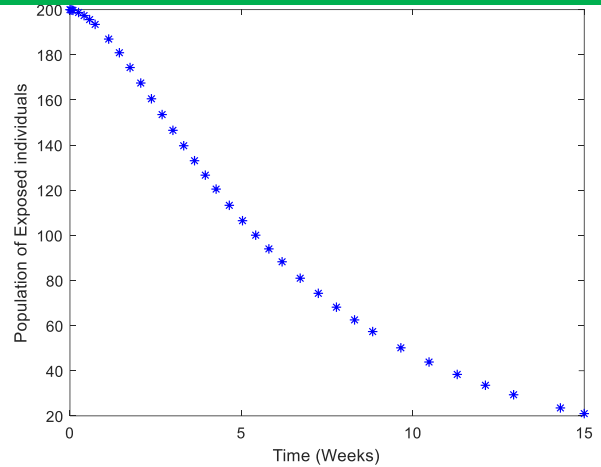


Figure 3: Diagram showing the dynamics of exposed Humans

Figure 3's curve illustrates how Ebola spread quickly during the first 14 weeks of the outbreak, but as time went on, people learned about the disease and adopted preventative measures, which led to the termination of Ebola in the final 15 weeks.

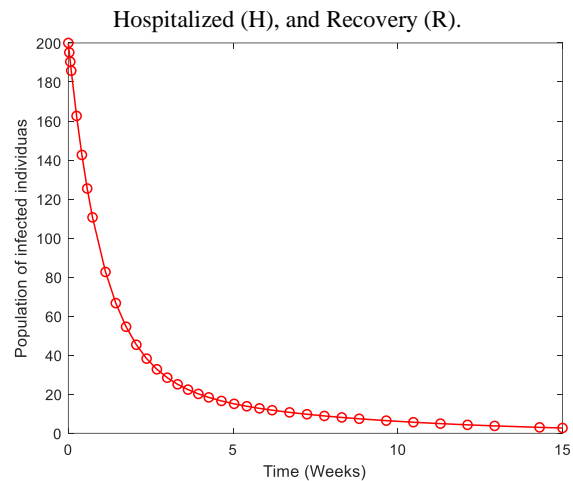


Figure 4: Diagram showing the dynamics of infected Humans

Figure 4 illustrates how, despite therapy, the infected Ebola cannot return to its original location.

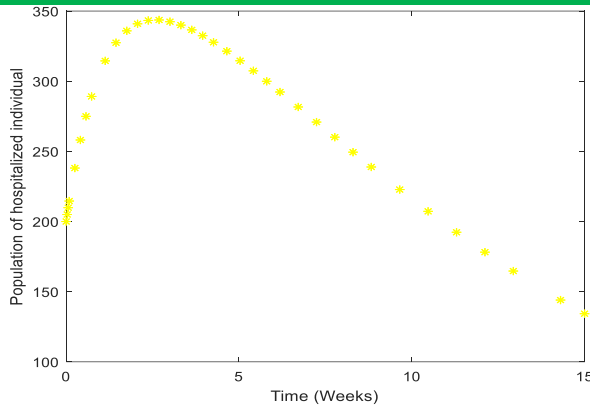


Figure 5: Diagram showing the dynamics of Hospitalized Humans

Figure 5, which shows the hospitalized patients, shows that during the first five weeks, the number of Ebola cases is still high because most medications are still being tested on humans at this time. After 15 weeks, the medication will show significant efficacy.

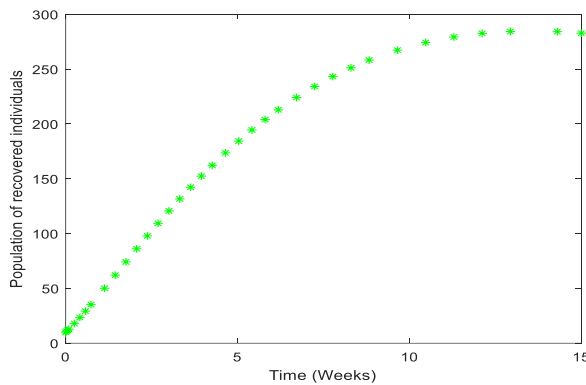


Figure 6: Diagram showing the dynamics of Recovered Humans.

Figure 6 illustrates how the number of recoveries keeps rising as a result of appropriate precautionary measures and good treatment.

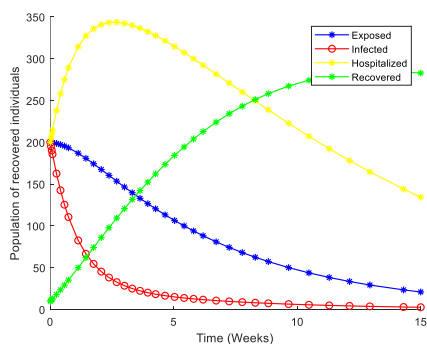


Figure 7: Diagram showing the dynamics of exposed, infected, Hospitalized and Recovered Humans.

The exposed figure illustrates how Ebola was high during the first week of the outbreak but declined further due to safety precautions and could not return to the origin without treatment; the infected compartment showed a high level during the outbreak but declined nearly to the origin due to treatment; the hospitalized compartment showed a high level during the first week due to drug experimentation but declined further due to appropriate medication administration; and the recovery compartment demonstrated that every individual could recover provided Ebola was identified and treated promptly.

5.0 CONCLUSION

The model was analyzed to find global stability, endemic equilibrium, freedom from diseases, bifurcation analysis, and reproduction number. The result of the bifurcation analysis shows that the model has a backward bifurcation. The analysis of the data suggests that global stability has been successfully reached and that the model is globally asymptotically stable. The recovery compartment in our graph illustrates that, with timely identification and treatment, Ebola can be contained and recovered from by anyone.

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