



INTERNATIONAL JOURNAL OF SCIENCE FOR GLOBAL SUSTAINABILITY

Unholy Stigma and Control of Leprosy a Mathematical Modeling Approach

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Received on: August, 2022

Revised and Accepted on: September, 2022

Published on: October, 2022

ABSTRACT

The disease that essentially affects the skin, the peripheral nerves, mucosal surfaces of the upper respiratory tract and the eyes. It is frequently surrounded by frightening, undesirable social stigmatization to them and their families and tales of leprosy patients being shunned as outcasts. In this paper, a deterministic mathematical model of the dynamics of disease is developed. The epidemic thresholds and equilibria for the model are determined and stabilities analyzed. Results from the analysis of the reproduction number propose that treatment will somehow contribute to a decrease in disease cases. This result recommends that, the control of the disease should lie more on treatment and public health education. Numerical simulations show the dynamics of the transmission of disease.

Keywords: unholy stigma, control, leprosy, Hansen's disease and mathematical modeling

1.0 Introduction

Leprosy, also known as Hansen's disease (HD), is a long-standing infectivity by the bacteria *Mycobacterium leprae* or *Mycobacterium lepromatosis*. The infectivity can lead to damage of the nerves, respiratory tract, skin, and eyes. This nerve damage possibly will upshot in a lack of ability to feel pain, which can lead to the loss of parts of a person's extremities from repeated injuries or infection due to unnoticed wounds. An infected person may also experience muscle weakness and poor eyesight. Leprosy symptoms may begin within one year, but for some people symptoms may take 20 years or more to occur (Ahn, Park, & Kweon (2020) & Mondiale de la Santé & WHO 2022).

Leprosy-related stigma is perhaps the oldest form of disease-related stigma known to man and, along with stigma against persons with mental illness, epilepsy, and, more recently, tuberculosis and HIV, is also the most widespread around the globe. The etiology of stigma may differ among conditions and cultural settings. For example, leprosy is often stigmatized because of the notion that the person

affected has committed a sin or broken a taboo, either in this or a previous life. The stigma may also be due to fear of the disfigurements it causes. In contrast, persons with schizophrenia suffer stigma because people perceive them to be unpredictable or dangerous, while persons living with HIV may be stigmatized because of the association with homosexuality and promiscuity or because of AIDS' characterization as a fatal and incurable disease. However, the manifestations and psychosocial consequences of stigma and discrimination are remarkably similar across conditions and cultures (Stangl, et al (2019), Hotez (2021) & Krendl & Pescosolido (2020)). The likely reason is that at the core of stigma is a common human response to difference is lack of consciousness, lack of education, lack of awareness, and the nature and complications of the illness.

Several studies on the history of leprosy provide evidence of racism and xenophobia. For example, studies have identified racism and xenophobia underlying discussions about migratory laws during The First Leprosy Conference in Berlin (Touati,

(2017)) and scientific investments in research on “Indian leprosy” (Robertson (2017)) The building of isolated leprosy settlements to protect the race from the “scourge” (Gundona (2015)). and the isolation of healthy children from leprosy-affected parents for eugenic reasons (Leite, Sampaio & Caldeira (2015) and public policy (Gussow (2021)) reflect similar biases.

The negative effects of stigmatization and discrimination on people affected by leprosy may be so intense that it could prevent them from seeking treatment. Compounding the situation is the fact that some health providers do not often have appropriate attitudes or the sensitivity to assist those affected by leprosy (Ibikunle, & Nwokeji, (2017)). In a study on knowledge and attitudes towards leprosy disease among healthcare workers in Guyana, Briden and Maguire found that many healthcare workers were afraid of leprosy, and believed the disease was contagious and incurable ((Ibikunle, & Nwokeji, (2017)) . In addition, Scott reported that some doctors refused to treat people affected by leprosy in India (Marahatta et al 2018). Moreover, due to stigma and discrimination, many people affected by leprosy may find it difficult to (a) involve themselves fully in society; (b) participate in educational activities; (c) engage in income-generation and employment ventures; and (d) exercise their civil and political rights (Somar et al. (2020) & Van ‘t Noordende et al (2019)):

2.0 Model Formulation

A deterministic $SE_1E_2I_1I_2R$ model with respect to *paucibacillary* leprosy and *multibacillary* leprosy with treatment and public health education as control measures are put in place to control the disease and its associated unholy stigma. The model divides the population concerned into Six, time dependent compartments: $S(t)$ —susceptible individuals who are yet to come into contact with the infection; $E_1(t)$ Individuals who have been exposed to *paucibacillary* leprosy but not yet infectious nor showing any symptoms; $E_2(t)$ Individuals who have been exposed to *multibacillary* leprosy but not yet infectious nor showing any symptoms; $I_1(t)$ are infectious

Unholy stigma also has an impact on people affected by the disease in terms of mental health, economic status, marriage and education, and timely and regular treatment. A study from Bangladesh showed that people affected by leprosy experience significantly more depression than the control group (Liu et al 2018)). The stress can even result in suicide as revealed by a study in South Africa, which reported that one third of patients’ contemplated suicide after learning their diagnosis of leprosy (van Dorst et al. (2020)). However, the manifestation of stigma may be different or change depending on visible signs, social status of people who have (had) leprosy, gender and social distance between affected persons and those who are stigmatized (Martos-Casado, Gil-Gonzalez & Vives-Cases (2020), Singh, Singh & Mahato,(2019) & Van’T Noordende et al (2021)):

This work is motivated by the work of (Raza & Rafiq (2022), Onah, et al (2019) & Martahi & Tasman (2021)), where deterministic compartmental modeling approach is used to design a model for the control of leprosy and its eradication. The paper is structured as follows: in section 2, we present the deterministic mathematical model, the analysis of the equilibrium points. While section 3 contains the analysis of the basic reproduction number. Numerical simulations are presented in section 4. The conclusion is presented in section 5.

individuals whose infection has progressed to *paucibacillary* leprosy from the compartment $E_1(t)$; $I_2(t)$ are infectious individuals whose infection has developed to *multibacillary* leprosy from the compartment; $E_2(t)$ — infectious class of individuals whose infection has advanced to *multibacillary* leprosy; and $R(t)$ —non-infectious group of people who have successfully recovered from the disease and are immune to re-infections.

$$\text{So that, } N = S + E_1 + E_2 + I_1 + I_2 + R$$

Susceptible individuals: The susceptible individuals are recruited via immigration at constant rate Λ . They decrease as a result of interaction with either *paucibacillary* or *multibacillary* leprosy infected individual at a rate

$\beta_1 I_1(t) + \beta_2 I_2(t)$. Where β_1 is the Effective contact rate of *paucibacillary* leprosy, β_2 Effective contact rate of *multibacillary* leprosy and ξ is the rate of public health education. The compartment also decreases as a result of natural death at a rate μ . Thus yields;

$$\frac{dS(t)}{dt} = \Lambda - (\beta_1 I_1(t) + \beta_2 I_2(t) + \mu - \xi)S(t)$$

Exposed individuals to *Paucibacillary* Leprosy:

The compartment are generated as a result of the interactions between the susceptible individuals with infected individuals with *paucibacillary* leprosy at a rate $\beta_1 I_1(t)$ and it decreases as a result of public health education, treatment, recovery and natural death. Thus,

$$\frac{dE_1(t)}{dt} = \beta_1 I_1(t)S(t) - (\alpha_1 + \vartheta + \mu + \gamma_1 + \xi)E_1(t)$$

Exposed individuals to *multibacillary* Leprosy:

The compartment are generated as a result of the interactions between the susceptible individuals with infected individuals with *multibacillary* leprosy at a rate $\beta_2 I_2(t)$ and it decreases as result of public health education, treatment, recovery and natural death. Thus,

$$\frac{dE_2(t)}{dt} = \beta_2 I_2(t)S(t) - (\alpha_2 + \vartheta + \mu + \gamma_2 + \xi)E_2(t)$$

Infected individuals with *Paucibacillary* Leprosy:

They are generated as a result of progression of exposed individuals with *Paucibacillary* leprosy to the compartment at a rate α_1 and decline as a result of public health education, treatment, recovery and natural death. Yields,

$$\frac{dI_1(t)}{dt} = \alpha_1 I_1(t) - (\vartheta + \mu + \mu_1 + \gamma_3 + \xi)I_1(t)$$

Infected individuals with *multibacillary* Leprosy:

They are generated as a result of progression of exposed individuals with

multibacillary leprosy to the compartment at a rate α_2 and decline as a result of public health education, treatment, recovery and natural death. Yields,

$$\frac{dI_2(t)}{dt} = \alpha_2 I_2(t) - (\vartheta + \mu + \mu_2 + \gamma_4 + \xi)I_2(t)$$

Recovered individuals: They are generated as a result of recovery of the exposed and infected compartments and it declines as result of natural death. Thus;

$$\frac{dR(t)}{dt} = \gamma_1 E_1(t) + \gamma_2 E_2(t) + \gamma_3 I_1(t) + \gamma_4 I_2(t) - \mu R(t)$$

The progression of the number of individuals in each compartment is described by the following system of ordinary differential equations

$$\frac{dS(t)}{dt} = \Lambda - (\beta_1 I_1(t) + \beta_2 I_2(t) + \mu - \xi)S(t)$$

$$\frac{dE_1(t)}{dt} = \beta_1 I_1(t)S(t) - (\alpha_1 + \vartheta + \mu + \gamma_1 + \xi)E_1(t)$$

$$\frac{dE_2(t)}{dt} = \beta_2 I_2(t)S(t) - (\alpha_2 + \vartheta + \mu + \gamma_2 + \xi)E_2(t)$$

$$\frac{dI_1(t)}{dt} = \alpha_1 I_1(t) - (\vartheta + \mu + \mu_1 + \gamma_3 + \xi)I_1(t)$$

$$\frac{dI_2(t)}{dt} = \alpha_2 I_2(t) - (\vartheta + \mu + \mu_2 + \gamma_4 + \xi)I_2(t)$$

$$\frac{dR(t)}{dt} = \gamma_1 E_1(t) + \gamma_2 E_2(t) + \gamma_3 I_1(t) + \gamma_4 I_2(t) - \mu R(t)$$

(2.1)

The associated model variables and parameters are described in Table 1 and 2.

**2.1 Basic properties of leprosy the Model
Positivity of Solutions**

We assume that all the parameters of the model (2.1) are positive and the initial conditions for (2.1) are

$$S_o(0) > 0, E_{10}(0) > 0, E_{20}(0) > 0, I_{10}(0) > 0, I_{20}(0), R_o(0) > 0, \mu < \xi \tag{2.2}$$

$$N'(t) = \Lambda - \mu N(t) - \mu_1 I_1(t) - \mu_2 I_2 + 4\xi \tag{2.5}$$

Lemma 2.1 solutions of (2.1) and (2.2) satisfy $S_o(0) > 0, E_{10}(0) > 0, E_{20}(0) > 0, I_{10}(0) > 0, I_{20}(0), R_o(0) > 0$. For all $t > 0$.

Proof

From the first equation of the model (2.1) we have

$$S' = \Lambda - (\beta_1 I_1(t) + \beta_2 I_2(t) + \mu - \xi)S(t) \tag{2.3}$$

Note that on $t \in [0, \infty)$ we have

$$S' \geq -(\beta_1 I_1(t) + \beta_2 I_2(t) + \mu - \xi)S(t)$$

So that, $S(t) \geq \tilde{S}(t)$ where \tilde{S} is the solution of

$$S' \geq -(\beta_1 I_1(t) + \beta_2 I_2(t) + \mu - \xi)S(t)$$

Satisfying $\tilde{S}(0) = S(0) > 0$. Clearly $\tilde{S}(t) > 0$ for all $t > 0$.

Following the same argument it can be shown that $E_{10}(0) > 0, E_{20}(0) > 0, I_{10}(0) > 0, I_{20}(0), R_o(0) > 0$ for all $t > 0$. The proof complete

2.2 Invariant regions

The leprosy model (2.1) will be analyzed in a biologically feasible region as follows.

$$D = D \subset \mathfrak{R}_+^6$$

with

$$D = \left\{ (S, E_1, E_2, I_1, I_2, R) \in \mathfrak{R}_+^6 : S + E_1 + E_2 + I_1 + I_2 + R = \Lambda \right\}$$

To established the positive invariance of D , the solutions of D remains in D for all $t > 0$. The rate of change of human population is given by

Assuming that death due to the infectivity is equal to zero (i.e. $\mu_1 = \mu_2 = 0$), and the public health education on against the stigma is insignificant it follows that

$$N'(t) = \Lambda - \mu N(t) \tag{2.6}$$

A standard comparison theorem (Nikravesch (2018)) can be used to show that

$$N(t) \leq N(0)e^{-(\mu-\xi)t} + \frac{\Lambda}{\mu-\xi} (1 - e^{-(\mu-\xi)t}) \tag{2.7}$$

And

Specifically,

$$N(t) \leq \frac{\Lambda}{\mu-\xi}, \text{ if } N(0) \leq \frac{\Lambda}{\mu-\xi} \tag{2.8}$$

respectively. Thus, the region D is positively – invariant. Hence, it is sufficient to consider the dynamic flows generated by (2.1) in D . The model can be considered as being epidemiological and mathematical well – posed in this region D (Bjørnstad et al (2020) & Abdullahi, Hasan & Abdullah (2014)). It is therefore sufficient to consider the dynamics of the flow generated by model system (2.1) in D . This result is summarized below.

Lemma 2.2 The region $D = D \subset \mathfrak{R}_+^6$ is positively – invariant for the model (2.1) with non-negative initial conditions in \mathfrak{R}_+^6

2.3 Disease – Free Equilibrium (DFE) and Stability Analysis

The model (2.1) has a DFE, defined by setting the right-hand sides of the equations in (2.1) to zero, given by

$$E_0 = (S^*, E_1^*, E_2^*, I_1^*, I_2^*, R^*) = \left(\frac{\Lambda}{\mu-\xi}, 0, 0, 0, 0, 0 \right)$$

2.4 Existence of Endemic Equilibrium Point (EEP)

Next, we investigate the endemic equilibrium points of the model that is the equilibria where at least one of the infected components of the model is non-zero, through the following steps. Let

$$E_1 = (S^{**0}, E_1^{**}, E_2^{**}, I_1^{**}, I_2^{**}, R^{**})$$

Indicates any arbitrary endemic equilibrium of the model. Solving the equations (2.1) at steady states with respect to the *paucibacillary* and *multibacillary*, respectively. Gives;

$$\begin{aligned} S^{**} &= \frac{(\xi - k_3)(-k_1 + \xi)}{\beta_1 \alpha_1} \\ E_1^{**} &= \frac{-\xi^3 + (\mu + k_1 + k_3)\xi^2 + ((-\mu - k_3)k_1 - \mu k_3)\xi - \Lambda \beta_1 \alpha_1 + \mu k_1 k_3}{\beta_1 \alpha_1 (-k_1 + \xi)} \\ E_2^{**} &= 0 \\ I_1^{**} &= \frac{\xi^3 + (-\mu - k_1 - k_3)\xi^2 + ((\mu + k_3)k_1 + \mu k_3)\xi + \Lambda \beta_1 \alpha_1 - \mu k_1 k_3}{\beta_1 (-k_1 + \xi)(\xi - k_3)} \\ I_2^{**} &= 0 \\ R^{**} &= \frac{(-\xi^3 + (\mu + k_1 + k_3)\xi^2 + ((-k_1 - \mu)k_3 - \mu k_1)\xi - \Lambda \beta_1 \alpha_1 + \mu k_1 k_3)(\gamma_1 \xi - \gamma_1 k_3 - \gamma_3 \alpha_1)}{\beta_1 (-k_1 + \xi)(\xi - k_3) \mu \alpha_1} \end{aligned} \quad (2.10)$$

and

$$\begin{aligned} S^{**} &= -\frac{k_4(\xi - k_2)}{\beta_2 \alpha_2} \\ E_1^{**} &= 0 \\ E_2^{**} &= -\frac{-\xi^2 k_4 + \xi k_4 k_2 + \mu k_4 \xi - \mu k_4 k_3 + \Lambda \beta_2 \alpha_2}{\beta_2 \alpha_2 (\xi - k_2)} \\ I_1^{**} &= 0 \\ I_2^{**} &= -\frac{-\xi^2 k_4 + \xi k_4 k_2 + \mu k_4 k_2 - \mu k_4 k_2 + \Lambda \beta_2 \alpha_2}{\beta_2 (\xi - k_2) k_4} \\ R^{**} &= -\frac{((\xi - k_2)(-\xi + \mu)k_4 + \Lambda \beta_2 \alpha_2)(\gamma_2 k_4 + \gamma_4 \alpha_2)}{\beta_2 \alpha_2 (\xi - k_2) \mu k_4} \end{aligned} \quad (2.11)$$

where $k_1 = \alpha_1 + \mathcal{G} + \mu + \gamma_1 - \xi$, $k_2 = \alpha_2 + \mathcal{G} + \mu + \gamma_2 - \xi$, $k_3 = \mu_1 + \mathcal{G} + \mu + \gamma_3 - \xi$,
 $k_4 = \mu_2 + \mathcal{G} + \mu + \gamma_4 - \xi$

3.0 Basic Reproduction Number \mathfrak{R}_0 .

The linear stability of leprosy can be established using the next generation operator method (Yakubu, Abdullah & Abdullahi (2021), Sule & Abdullah (2019) & Abdullahi, Hasan and Abdullah (2015)) in the model equation (2.1), the matrix F and V , for the new infection terms and the remaining transfer terms, are respectively, given by:

$$F = \begin{pmatrix} 0 & 0 & \frac{\beta_1 \Lambda}{\mu - \xi} & 0 \\ 0 & 0 & 0 & \frac{\beta_1 \Lambda}{\mu - \xi} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \quad (3.1)$$

$$V = \begin{pmatrix} \alpha_1 + \vartheta + \mu + \gamma_1 + \xi & 0 & 0 & 0 \\ 0 & \alpha_2 + \vartheta + \mu + \gamma_2 + \xi & 0 & 0 \\ -\alpha_1 & 0 & \mu_1 + \vartheta + \mu + \gamma_3 + \xi & 0 \\ 0 & -\alpha_2 & 0 & \mu_2 + \vartheta + \mu + \gamma_4 + \xi \end{pmatrix} \quad (3.2)$$

The basic reproduction number, denoted by $R_0 = \rho(FV^{-1})$, where ρ denotes the spectral radius, is given by;

$$R_0 = \frac{\Lambda(\beta_1 \alpha_1 + \beta_2 \alpha_2)}{(\mu - \xi)(\alpha_2 + \vartheta + \mu + \gamma_2 + \xi)(\mu_2 + \vartheta + \mu + \gamma_4 + \xi)(\alpha_1 + \vartheta + \mu + \gamma_1 + \xi)(\mu_1 + \vartheta + \mu + \gamma_3 + \xi)} \quad (3.3)$$

Using by Theorem 2 of [27], the following result is established.

R_0 Can express as the sum of two quantities $R_0 = R_{I_1} + R_{I_2}$

$$R_{I_1} = \frac{\beta_1 \Lambda \alpha_1}{(\mu - \xi)(\alpha_1 + \vartheta + \mu + \gamma_1 + \xi)(\mu_1 + \vartheta + \mu + \gamma_3 + \xi)} \quad (3.4)$$

and

$$R_{I_2} = \frac{\beta_2 \Lambda \alpha_2}{(\mu - \xi)(\alpha_2 + \vartheta + \mu + \gamma_2 + \xi)(\mu_2 + \vartheta + \mu + \gamma_4 + \xi)} \quad (3.5)$$

The two quantities represent the basic reproductive numbers for the *paucibacillary* and *multibacillary*, respectively.

Theorem 1 The DFE of model equation (2.1), given (2.9), are locally asymptotically stable (LAS) if $R_0 < 1$, and unstable if $R_0 > 1$. (Abdullahi, Hasan & Abdullah (2015) & Mamuda, et al (2017)) The threshold quantity R_0 is the basic reproduction number of the disease. It is the expected average number of new infections produced by infective human (leprosy) when

introduced into a completely susceptible population.

3.0 Analysis of the Basic Reproduction Number R_0 .

The basic reproduction number R_0 decreasing function of ξ as;

$$\lim_{\xi \rightarrow \infty} R_0 = 0. \quad (3.1)$$

This suggests that increase in public health education will have positive impact on reducing the unholy leprosy stigma. However, we explore the

impact of treatment of leprosy by differentiating the two basic reproduction numbers partially with respect to treatment. Thus yields;

$$\frac{\partial \mathcal{R}_{I_1}}{\partial \vartheta} = -\frac{\beta_1 \Lambda \alpha_1 (\mu_1 + 2\vartheta + 2\mu + \gamma_3 - 2\xi + \alpha_1 + \gamma_1)}{(\mu - \xi)(\alpha_1 + \vartheta + \mu + \gamma_1 + \xi)^2 (\mu_1 + \vartheta + \mu + \gamma_3 + \xi)^2} \tag{3.2}$$

$$\frac{\partial \mathcal{R}_{I_1}}{\partial \vartheta} < 0 \tag{3.3}$$

Similarly,

$$\frac{\partial \mathcal{R}_{I_2}}{\partial \vartheta} = -\frac{\beta_2 \Lambda \alpha_2 (\mu_2 + 2\vartheta + 2\mu + \gamma_4 - 2\xi + \alpha_2 + \gamma_2)}{(\mu - \xi)(\alpha_2 + \vartheta + \mu + \gamma_2 + \xi)^2 (\mu_2 + \vartheta + \mu + \gamma_4 + \xi)^2} \tag{3.4}$$

$$\frac{\partial \mathcal{R}_{I_2}}{\partial \vartheta} < 0 \tag{3.5}$$

The fact that $\frac{\partial \mathcal{R}_0}{\partial \vartheta} < 0$ suggests that increase in treatment of infected humans with leprosy will decrease the infectivity in a community.

4.0 Numerical Simulations

The simulations were carried out using the following values for initial conditions. Computations were run in Maple 17.

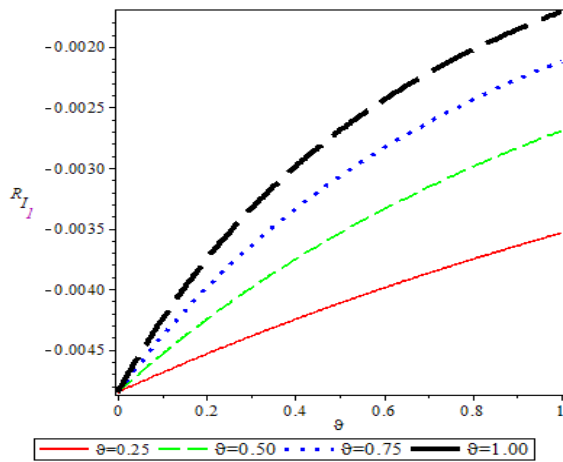


Figure 1: Effect of Treatment on exposed and infected individuals with *Paucibacillary leprosy*

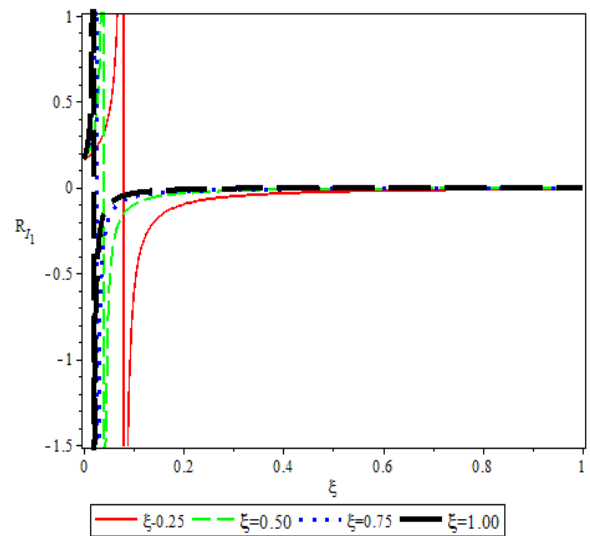


Figure 2: Effect of Public health education on exposed and infected individuals with *Paucibacillary leprosy*

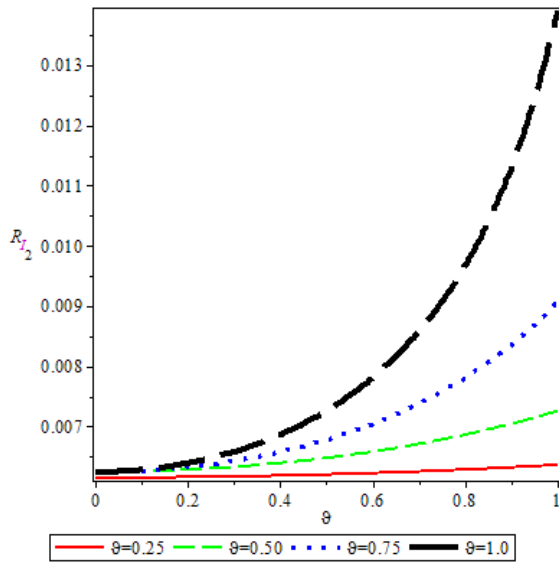


Figure 3: Effect of Treatment on exposed and infected individuals with Multibacillary leprosy

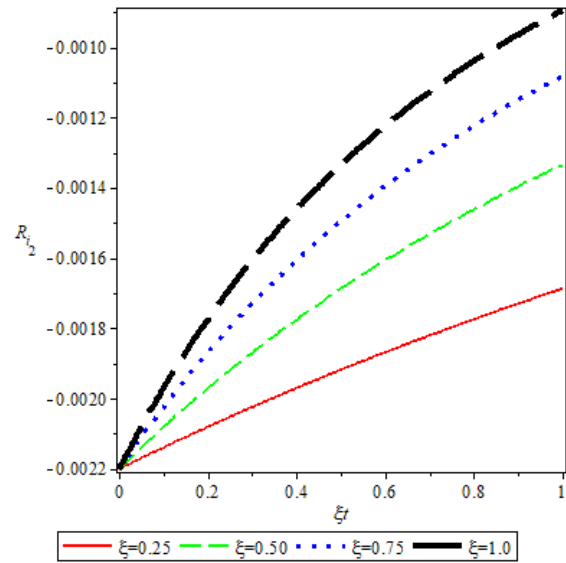


Figure 4: Effect of public health education on exposed and infected individuals with Multibacillary leprosy

Table 1: Description of variables for Leprosy model

Variables	Description
S	Susceptible human
E_1	Exposed human to <i>Paucibacillary leprosy</i>
E_2	Exposed human to <i>Multibacillary leprosy</i>
I_1	Infected human to <i>Paucibacillary leprosy</i>
I_2	Infected human to <i>Multibacillary leprosy</i>
R	Recovered human

Table 2: Description of parameters for Leprosy model

Par.	Description	Est. Value	Ref
Λ	Human recruitment rate	0.2/year	Raz& Rafiq ,(2022)
β_1	Effective contact rate of <i>paucibacillary</i>	0.15	Raz& Rafiq, (2022)
β_2	Effective contact rate of <i>multibacillary</i>	0.3	Raz& Rafiq, (2022)
μ	Natural death	0.02	Raz& Rafiq, (2022)
μ_1	Disease – induced death due to <i>paucibacillary</i>	0.2	Raz& Rafiq, (2022)
μ_2	Disease – induced death due to <i>multibacillary</i>	0.05	Raz& Rafiq, (2022)
ϑ	Treatment $0 < \vartheta \leq 1$	Assumed	
ξ	Public health education $0 < \xi \leq 1$	Assumed	

α_1	Rate of progression from exposed individuals to <i>paucibacillary</i>	0.2	Raz& Rafiq, (2022)
α_2	Rate of progression from exposed individuals to <i>multibacillary</i>	0.1	Raz& Rafiq, (2022)
γ_1	Recovery rate from E_1	0.63	Assumed
γ_2	Recovery rate from E_2	0.65	Assumed
γ_3	Recovery rate from I_1	0.65	Onah, (2019)
γ_4	Recovery rate from I_2	0.63	Onah, (2019)

5.0 CONCLUSION

In this paper, a deterministic mathematical model for leprosy that incorporated two exposed classes was developed. The model is locally asymptotically stable when $\mathfrak{R}_0 < 1$ and unstable for $\mathfrak{R}_0 > 1$. Results from the analysis of basic reproduction number suggest that treatment and public health education will contribute to the reduction in leprosy cases and unholy stigma. This result suggests the control of leprosy and unholy stigma lie more on treatment and public health education. Thus, more

efforts need to be done in addressing issues such as effective treatment and public health education so that the disease will successfully be controlled and can easily be eradicated. Tailor-made education should be carried out as part of de-stigmatizing interventions, taking attitudes and perceptions of the community into consideration. Importantly, such interventions should be sustained to facilitate a gradual reduction of stigma in the long run. Numerical simulations show the dynamics of the transmission of the infectivity.

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