IMPACT OF AWARENESS DRIVEN BY MEDIA EFFORTS ON THE SPREAD OF HIV INFECTION

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ABSTRACT

In this paper, a non-linear mathematical model is proposed to study the impact of awareness driven by media efforts on the dynamics of HIV. The awareness spread in the population is taken in two aspects self motivated and media driven. It is assumed thatdue to awareness of the disease some susceptible are becoming cautious or aware about the disease and start taking necessary precautionary actions to protect themselves while some people require encouragement or efforts to drive them towards followingthe necessary precautions. For such people who require to be driven on the way of awareness the media efforts are made to makelarger number of susceptible aware. Due to the awareness, susceptible are taking necessary care to remove the possibility to contact with HIV infected.A global qualitative analysis and numerical simulations are carried out to show that typical threshold behavior hold for the proposed non-linear compartmental model.

KEYWORDS: Awareness, Basic reproduction number; awareness; stability.

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1. INTRODUCTION

The Mathematical modeling is a powerful tool to study and control the spread of infectious diseases in the population. It helps to control the disease by providing useful prediction about the effectiveness of possible thresholds.There are many factors responsible for the spread of diseases such as interaction between susceptible and infected which is given by the different kind of function responses, available effective treatment which is useful to control the disease by curing infected population, vaccination which gives immunity to susceptible against the disease, awareness which helps the aware population to protect against the disease by some necessary precautionary actions, migration of population which helps us the migrated population keep to be away from the disease spreading region.In modern age the emergenceof some diseases in particular HIV/AIDS for which effective treatment to cure the infected or vaccination to supply the immunity to the population at risk is not available. For such diseases, the awareness is the most important factor to control the spread.

For many infectiousdiseases like HIV infection, prevention is desirable and it is the only way to reduce the risk of contracting the infection. By the time that most people become sexually active or comes at the risk of contracting HIV infection by means of sexual relations, it is likely that many will be aware of the potential risk of becoming infected and of the measures that can be taken to avoid becoming infected. In case of children who can contract the infection by some other means of disease transmission the awareness of their parents can take care to protect them from the disease. But, the most important factor is the willingness or responsiveness of individuals to act upon the information that is made available. Here the willingness or responsiveness can be termed as awareness. To reflect this in the model, we differentiate between individuals based on the willingness to respond to the information generated by the presence of the disease.Individuals that are not yet infected and are willing to respond can take basic precautionary measures to reduce/remove their probability of becoming infected. If infected, responsive individuals are likely to seek treatment early and thus have a shorter infectious period or less sufferingfrom the disease compared to infected individuals that remain passive or non responsive. The willingness to respond depends on the severity of disease, length of infection, availability of effective treatment etc. If susceptible individuals are less cautious as a result of limited information then the information can be provided by the media efforts. These are important factors that are incorporated in the model.Human reactions in the presence of disease abound can be as follows. (1). From avoiding social contact with infected individuals(*social distancing*) to wearing protective masks, vaccination,or some other possible precautions. It has been shown, for instance,that local measles outbreaks are correlated with the demand formeasles, mumps, and rubella vaccines (2). Similarly, the demandfor condoms rises in areas where AIDS is prevalent (3), and condomuse has been linked to the knowledge of someone who hasdied of AIDS (4).Behavior that is responsive to the presence of a disease canpotentially reduce the size of an epidemic outbreak. On closerinspection, it is not so much the presence of the disease itself thatwill prompt humans to change their behavior, as *awareness* of thepresence of the disease. A change in behavior can be promptedwithout witnessing the disease first hand, but by being informedabout it through others or also through media efforts. This information in itself will spreadthrough the population and have its own dynamic. (5).Causing people to stay homeor wear face masks when going outside.

We understand awareness as the possessionof information about the disease outbreak due to which one is willing to act to be protected.

media coverage or government programs without taking action.with more informed individuals actingto reduce/remove their susceptibility.This will allow us to show how awareness canreduce the number of individuals infected during an epidemic,while the threshold for disease invasion, and thus the forcefor outbreaks, can be affected.

It is observed that the spread of the infectious or communicable diseases in the population make the people to change their behavior and attitude to prevent themselves and others from contracting the disease[1]. These changes in the behavior may be called awareness. Some members of population are veryhealth conscious and they don't require any encouragement but they themselves are self motivated to keep them protected from life threatening or chronic diseases. But the some othersrequire some encouragements or efforts to get them convinced to follow the precautionary measures. To convince such people media efforts can be made to explore the risk and severity of the disease and benefits of following necessary preventive actions for the disease.This media efforts are made by government health authorities or social institutions depending on the force of infection in the population. Because more efforts are to be made if there is more infection in the population and if there is no infection or negligible infection in the population then there is no need to spare money to make media efforts. Such media efforts can be quantified by number advertisements in the news papers radio or television or some other possible means. Such number can be very large so that continuity of media effort can be considered. The level of awareness not only depends on the behavioral changes imposed by public authorities, but also depends on responses driven by risk and fear of the given disease. Here fear of the disease is due to its effects on the life, duration of the sickness of the disease and most importantly non-availability of the effective treatment of the disease. Kristiansen et al. [2] in his workexplored the usage of face masks to avoid airborne diseases. Rubin et al. [3] showed the importance of using better hygiene. Laver et al. [4] in their study of malaria considered importance of preventive medicine. Ahituv et al. [5] explored the demand of practicing safer sex using condoms. These actions can change the dynamics of the disease. For people to react in some way, they do not necessarily need to have seen/experience the effects of the disease themselves, but they may have heard of it through some media sources. These, however, usually focus on diseases like HIV/AIDS, Tuberculosis etc. As the information about the presence of a disease spreads in the population, people adapt their behavior as a result of their awareness of the disease (e.g., Stone burner and Low-Beer,[6]).

It is the awareness which make people to take precautions such as vaccination, screening of donated blood to prevent blood borne diseases, adapting to protected sex to prevent sexually transmitted diseases. It has been observed in statistical analysis on AIDS awareness programs that public awareness can play an appreciable role in preventing the AIDS epidemic [7]. Some researchers have proposed and analyzed compartmental models with the assumption that the awareness plays a vital role to reduce the disease spread [8, 12]. Misra et al.[13] have proposed and analyzed a non-linear mathematical model for the effects of awareness programs on the spread of infectious diseases such as flu has been proposed and analyzed.

2. THE MODEL

The total population of interest is divided into three mutual disjoint compartments, susceptible class (C_1), aware class (C_2) without HIV infection whose members are taking sufficient precautionary actions to protect themselves from HIV infection, HIV infected class (C_3) whose members are unaware about their own infection or even if they are aware about their infection then also they are not taking sufficient action to stop further spread of HIV. Let $S(t), S_h(t)$ and $I_1(t)$ be the number of individuals at time t in these compartments C_1, C_2, and C_3 respectively. Let N be the total population size at time t such that $N(t) = S(t) + S_h(t) + I_1(t)$.

Let ω be the recruitment rate while D is the natural death rate in the population. The susceptible become HIV infected following contact with the HIV infective at the contact rate α.In absence of media efforts also, some individualsof susceptible class are very much health conscious and keep themselves updated and aware about the disease. Such people are self motivated to take precautionary actions so they are getting transferred from the susceptible compartment C_1 to aware compartment C_2 at the rate m_1. There are some people in the susceptible can be convinced by some efforts to follow precautionary measures to protect themselves from the disease for such people some number of media efforts/meetings are made. Let $M(t)$ be number of the media efforts/meeting to increase the awareness in the susceptible class. The growth rate of this number $M(t)$ is proportional to the number of infected individuals in class C_3 because if there is more infection spread in the population then health authorities or government will make more efforts to control the disease. Let C be the rate with which media efforts are being conducted to increase the awareness and F represents the failure rate of these media efforts due to its ineffectiveness.Under the influence of media efforts, some individuals are getting aware and transferred from the compartment C_1 to C_2 at the rate m_2 this transfer is followed by Holling type II function response because after certain number of efforts/meetings the effect diminishes. D_1 is the death due to disease in the infective classes C_3

The compartmental model is developed according to the above discussed assumptions.

$$\frac{\mathrm{dS}}{\mathrm{dT}} = \omega - \alpha S I_1 - m_1 S - \frac{m_2 S M}{K+M} - DS$$
$$\frac{\mathrm{d}S_h}{\mathrm{dT}} = m_1 S + \frac{m_2 S M}{K+M} - DS_h$$
$$\frac{\mathrm{d}I_1}{\mathrm{dT}} = \alpha S I_1 - (D + D_1) I_1$$
$$\frac{\mathrm{dM}}{\mathrm{dT}} = C I_1 - FM$$

(2.1)

All parameters are assumed to be nonnegative. The initial conditions associated with the system are:

$$S(0) = S_0 \geq 0, S_h(0) = S_{h0} \geq 0, I_1(0) = I_{10} \geq 0, M(0) = M_0 \geq 0 \quad (2.2)$$

For non-dimensional form of the system, consider the following new dimensionless state variables and parameters:

$$t = DT,\ s=\frac{\mathrm{DS}}{\omega},\ i_1=\frac{\mathrm{DI_1}}{\omega},\ s_h=\frac{\mathrm{DS_h}}{\omega},\ m=\frac{\mathrm{M}}{K},\ d_1=\frac{\mathrm{D_1}}{D},$$
$$\mathrm{A}=\frac{\alpha\omega}{D^2},\ c=\frac{C\omega}{KD^2},\ \mu_1=\frac{m_1}{D},\ \mu_2=\frac{m_2}{D},\ f=\frac{F}{D}$$

The dimensionless form of the system (2.1) and the initial conditions (2.2) are

$$\frac{\mathrm{d}s}{\mathrm{dt}} = 1 - Asi_1 - \mu_1 s - \frac{\mu_2 sm}{1+m} - s$$
$$\frac{\mathrm{d}s_h}{\mathrm{dt}} = \mu_1 s + \frac{\mu_2 sm}{1+m} - s_h$$
$$\frac{\mathrm{d}i_1}{\mathrm{dt}} = Asi_1 - (1+d_1)i_1$$
$$\frac{\mathrm{d}m}{\mathrm{dt}} = ci_1 - fm$$

(2.3)

$$s(0) = s_0 \ge 0, s_h(0) = s_{h0} \ge 0, i_1(0) = i_{10} \ge 0, m(0) = m_0 \ge 0$$

(2.4)

3 Analysis

It is observed that all solutions of the system (2.2) with nonnegative initial data will remain nonnegative $t > 0$. The proof is straightforward application of Nagumo's theorem. [14]

Theorem 3.1 All the solutions of equation (2.3) which initiate in $R_+^{\ 4}$ are uniformly bounded.

Proof: Adding the first three equations of the system (2.3)

$$\frac{\mathrm{d}n}{\mathrm{d}t} = 1 - n - d_1 i_1$$
$$\frac{\mathrm{d}n}{\mathrm{d}t} + n \le 1$$

Applying theory of differential equation for the above equation

$$0 < n(s, s_h, i_1) \le (1 - e^{-t}) + n(s(0),\ s_h(0),\ i_1(0),\ i_2(0))e^{-t}$$

Sofor $t \to \infty$,

$$0 < n(s, s_h, i_1) \le 1$$

Clearly i_1 is bounded as n is bounded and from the last equation of the system (2.3) it can be easily proved that $\limsup_{t\to\infty} m(t) \le \frac{c}{f}$

Hence, all the solutions of eq. (2.3) that initiate in R_+^4 are confined to the region

$$\Omega = \left\{ (s, s_h, i_1, m) \in \mathrm{R}_+^4 : 0 \le s + s_h + i_1 \le 1, 0 \le m(t) \le \frac{c}{f} \right\}$$

The following Equilibrium points of the non-linear dynamical system (2.3) are obtained:

The disease free equilibrium point $E_0(s^*,\ s_h^*,\ 0,\ 0)$ always exists and

$$s^* = \frac{1}{(1+\mu_1)},\ s_h^* = \frac{\mu_1}{(1+\mu_1)}.$$

The endemic equilibrium $E_1(\bar{s}, \bar{s}_h, \bar{i}_1, \bar{i}_2)$ is obtained by solving the four simultaneous equations:

$$1 - Asi_1 - \mu_1 s - \frac{\mu_2 sm}{1+m} - s = 0 \quad (3.1a)$$

$$\mu_1 s + \frac{\mu_2 sm}{1+m} - s_h = 0 \quad (3.1b)$$

$$As - \delta = 0;\ \delta = 1 + d_1 \quad (3.1c)$$

$$ci_1 - fm = 0 \quad (3.1d)$$

Solving (3.1c), gives

$$\bar{s} = \frac{\delta}{A}. \quad (3.2a)$$

Solving (3.1d), gives

$$\bar{i}_1 = \frac{f\bar{m}}{c} \quad (3.2b)$$

This substitution of (3.2a) in the equation (3.1b) yields

$$\bar{s}_h = \frac{\delta\left\{\mu_1 + \bar{m}\left(\mu_1 + \mu_2\right)\right\}}{A(1+\bar{m})} \quad (3.2c)$$

Substitution of the values of s and m in equation (3.1a) gives a quadratic equation

$$m^2 + \left\{1 - \frac{c\left(A - \delta(1+\mu_1+\mu_2)\right)}{Af\delta}\right\} m + \left\{\frac{c\left(\delta(1+\mu_1) - A\right)}{Af\delta}\right\} = 0 \quad (3.2d)$$

Taking $R_0 = \dfrac{A}{\delta(1+\mu_1)}$ (3.3)

When $R_0 < 1$, then equation (3.2c) has no any positive solution and if $R_0 > 1$ then equation (3.2c) unique positive solution $\bar{m}$. Therefore when $R_0 > 1$, the system (2.3) has a unique endemic equilibrium point $E_1(\bar{s}, \bar{s}_h, \bar{i}_1, \bar{m})$ where thevalue $\bar{s}$, $\bar{s}_h$ and $\bar{i}_1$ of are given by the equation(3.2a), (3.2b) and (3.2c) respectively while the unique positive value of $\bar{m}$ is the root of (3.2d). Here, R_0 is a threshold for the existence of the endemic equilibrium point and hence it is clearly seen that R_0 is a basic reproduction number.

The endemic $E_1(\bar{s}, \bar{s}_h, \bar{i}_1, \bar{i}_2)$ equilibrium point exists if

$$\mathrm{R}_0 > 1 \quad (3.4)$$

It may be observed from the system (3.1) that the existence of any other point except these two, namely E_0 and E_1, is not possible.

3.1 Stability Analysis

The local stability of different equilibrium points can be discussed on the basis of stability matrix at $\mathrm{E}(s, s_h, i_1, i_2)$. Itis computed as

$$J = \begin{bmatrix} -1-\mu_1-\mathrm{A}i_1-\dfrac{\mu_2 m}{1+m} & 0 & -As & -\dfrac{\mu_2 s}{(1+m)^2} \\ \mu_1+\dfrac{\mu_2 m}{1+m} & -1 & 0 & \dfrac{\mu_2 s}{(1+m)^2} \\ \mathrm{A}i_1 & 0 & As-\delta & 0 \\ 0 & 0 & c & -f \end{bmatrix}$$

The stability results are statedbelow in the form of theorems.

Theorem 1 The disease-free equilibrium $E_0\left(\mathrm{s}^*, \mathrm{s}_h{}^*, 0, 0\right) = E_0\left(\dfrac{1}{(1+\mu_1)}, \dfrac{\mu_1}{(1+\mu_1)}, 0, 0\right)$ is locally asymptotically stable when

$$\mathrm{R}_0 < 1 \quad (3.5)$$

Proof: The eigenvalues of the stability matrix J at E_0 are computed as $-(1+\mu_1), -1, -\left(\delta - \dfrac{A}{1+\mu_1}\right), -f$. 173

Clearly, all eigenvalues are negative if $\delta + \mu_2 - \dfrac{A}{1+\mu_1} > 0$ or $\mathrm{R}_{01} < 1$.

Hence, the result is proved. □

Remark: since the s_h does not appear in the equations of the system (2.3), the system can be reduced to system of three equations. In that case the stability matrix can be obtained by ignoring second row and second column of the matrix J. So for further discussion it is not necessary to consider the second equation of the system (2.3) and it is sufficient to consider system with three equations only.

$$\frac{\mathrm{ds}}{\mathrm{dt}} = 1 - Asi_1 - \mu_1 s - \frac{\mu_2 sm}{1+m} - s$$
$$\frac{\mathrm{d}i_1}{\mathrm{dt}} = Asi_1 - \delta i_1$$
$$\frac{\mathrm{d}m}{\mathrm{dt}} = ci_1 - fm$$
(3.6)

Clearly, when $R_0 < 1$ there will be no disease and when $R_0 > 1$ disease will persist in the population. Also, the basic reproduction number depends on the parameters μ_1 and δ.

Remark: It may be noted from (3.4) that the local stability of E_0 ensures the non-existence of other equilibrium point E_1. Therefore, when $R_0 < 1$, one may expect E_0 to be globally stable which is proved by using geometric approach for the global stability inthe following theorem using geometric approach for the global stability [15].

Theorem 2 The locally stable disease-free equilibrium, $E_0(\mathrm{s}^*, s_h^*, 0, 0)$ is always globally asymptotically stable

Proof: The Jacobian matrix of the system (3.6) around a equilibrium point $E_0(\mathrm{s}^*, 0, 0)$ is

$$J(E_0) = \begin{bmatrix} -(1+\mu_1) & -\frac{A}{1+\mu_1} & -\frac{\mu_2}{1+\mu_1} \\ 0 & \frac{A}{1+\mu_1} - \delta & 0 \\ 0 & c & -f \end{bmatrix}$$

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The second additive compound Matrix is obtained as

$$J^{(2)}(E_0) = \begin{bmatrix} \frac{A}{1+\mu_1} - (1+\mu_1+\delta) & 0 & \frac{\mu_2}{1+\mu_1} \\ c & -(1+\mu_1+f) & -\frac{A}{1+\mu_1} \\ 0 & 0 & \frac{A}{1+\mu_1} - (1+d_1+f) \end{bmatrix}$$

Define a function $P \in C^1$ as

$$P(s,i,m) = diag\{s,s,s\}$$

Clearly, $P_f P^{-1} = diag\left\{\frac{\dot{s}}{s}, \frac{\dot{s}}{s}, \frac{\dot{s}}{s}\right\}$ and is a vector field of (2.3)

$$PJ^{(2)}P^{-1} = J^{(2)}$$

Taking $B = P_f P^{-1} + PJ^{(2)}P^{-1}$

$$B = \begin{bmatrix} \frac{A}{1+\mu_1} - (1+\mu_1+\delta) + \frac{\dot{s}}{s} & 0 & \frac{\mu_2}{1+\mu_1} \\ c & \frac{\dot{s}}{s} - (1+\mu_1+f) & -\frac{A}{1+\mu_1} \\ 0 & 0 & \frac{A}{1+\mu_1} + \frac{\dot{s}}{s} - (1+d_1+f) \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}$$

Where,

$$B_{11} = \frac{A}{1+\mu_1} - (1+\mu_1+\delta) + \frac{\dot{s}}{s}, \; B_{12} = \begin{bmatrix} 0 & \frac{\mu_2}{1+\mu_1} \end{bmatrix}, \; B_{21} = \begin{bmatrix} c \\ 0 \end{bmatrix},$$

$$B_{22} = \begin{bmatrix} \frac{\dot{s}}{s} - (1+\mu_1+f) + \frac{\dot{s}}{s} & \frac{A}{1+\mu_1} \\ 0 & \frac{A}{1+\mu_1} - (\delta+f) + \frac{\dot{s}}{s} \end{bmatrix}$$

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Consider now the norm in R^3 as

$$\left|(u,v,w)\right| = \max\{|u|, |v+w|\}$$

Where, (u,v,w) denote the vector in and μ denote the Lozinski measure with respect this norm. The Lozinski norm $\mu(B)$ with respect the norm $|.|$ can be estimated asfollows [16]:

$$\mu(B) = \max\{g_1, g_2\}$$
$$= \max\{\mu(B_{11}) + |B_{12}|, \mu(B_{22}) + |B_{21}|\}$$

$$g_1 = \frac{\dot{s}}{s} - 1 - \mu_1 - \delta + \frac{A}{1+\mu_1} + \mu_2,$$

Where,

$$g_2 = \frac{\dot{s}}{s} + \max\left\{-1 - f - \mu_1, -f - \delta + \frac{A}{1+\mu_1}\right\} + c$$

If the conditions

$$R_0 \le 1, 1+\mu_1 > \mu_2 \; f > c - \max\left\{-1-\mu_1, \delta - \frac{A}{1+\mu_1}\right\}$$

(3.7)

hold than there exist a number $w > 0$ such that

$$\mu(B) \le \frac{\dot{s}}{s} - w$$

Hence, $\frac{1}{t}\int_0^t \mu(B)ds \le \frac{1}{t}\frac{\log(s)}{s_0} - w$.

The Bendixson's criterion given by [17] is thus verified if the conditions given by (3.7) are true.

Theorem3 The endemic equilibrium $E_1(\bar{s}, \bar{s}_h, \bar{i}_1, \bar{i}_2)$, if it exists, is locally asymptotically stable.

Proof: The characteristic equation of stability matrix at E_1 is obtained as

$$(\lambda+1)(\lambda^3 + a_0\lambda^2 + a_1\lambda + a_2) = 0$$

$$a_0 = 1 + f + \mu_1 + \frac{A}{c} + \frac{\mu_2 \bar{m}}{(1+\bar{m})} > 0;$$

$$a_1 = \frac{f\ (\mathrm{A}\ (\delta + f)\ \bar{m}\ (1 + \bar{m}) + \mathrm{c}\ (1 + \mu_1\ + \mathrm{M}\ (1 + \mu_1\ + \mu_2)))}{\mathrm{c}\ (1 + \bar{m})} > 0.$$

$$a_2 = \frac{(\delta f \bar{m}\ (\mathrm{A} f\ (1 + \bar{m})^2\ + c\ \mu_2))}{\mathrm{c}(1 + \bar{m})^2} > 0$$

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By the Routh Hurwitz's criteria all the roots of the cubic factor of equation (3.6) are having negative real parts.

Hence, the result is proved. □

Theorem 4 The locally stable equilibrium point $E_1(\bar{s}, \bar{s}_h, \bar{i}_1, \bar{i}_2)$ is globally asymptotically stable.

Proof:Proof: The Jacobian matrix of the system (3.6) around a equilibrium point $E_1(\bar{s}, \bar{i}, \bar{m})$ is

$$J(E_1) = \begin{bmatrix} -\left(1 + \mu_1 + \frac{Af\bar{m}}{c} + \frac{\mu_2}{1+\bar{m}}\right) & -\delta & -\frac{\delta\mu_2}{A(1+\bar{m})^2} \\ \frac{Af\bar{m}}{c} & 0 & 0 \\ 0 & c & -f \end{bmatrix}$$

The second additive compound Matrix is obtained as

$$J^{(2)}(E_1)=\begin{bmatrix} -\left(1+\mu_1+\frac{Af\bar{m}}{c}+\frac{\mu_2}{1+\bar{\bar{m}}}\right) & -\delta & \frac{\delta\mu_2}{A(1+\bar{\bar{m}})^2} \\ c & -\left(1+\mu_1+f+\frac{Af\bar{m}}{c}+\frac{\mu_2}{1+\bar{\bar{m}}}\right) & \delta \\ 0 & \frac{Af\bar{m}}{c} & -f \end{bmatrix}$$

Define a function

$$P(s,i,m)=diag\left\{s,s,s\right\} \text{ and clearly, } P_f P^{-1}=diag\left\{\frac{\dot{s}}{s},\frac{\dot{s}}{s},\frac{\dot{s}}{s}\right\}$$

$$PJ^{(2)}P^{-1}=J^{(2)}$$

Taking

$$B=P_f P^{-1}+PJ^{(2)}P^{-1}$$

$$B=\begin{bmatrix} -\left(1+\mu_1+\frac{Af\bar{m}}{c}+\frac{\mu_2}{1+\bar{\bar{m}}}\right)+\frac{\dot{s}}{s} & 0 & \frac{\delta\mu_2}{A(1+\bar{\bar{m}})^2} \\ c & -\left(1+\mu_1+f+\frac{Af\bar{m}}{c}+\frac{\mu_2}{1+\bar{\bar{m}}}\right)+\frac{\dot{s}}{s} & -\delta \\ 0 & \frac{Af\bar{m}}{c} & -f+\frac{\dot{s}}{s} \end{bmatrix}=\begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}$$

Where,

$$B_{11}=-\left(1+\mu_1+\frac{Af\bar{m}}{c}+\frac{\mu_2}{1+\bar{\bar{m}}}\right)+\frac{\dot{s}}{s}, \quad B_{12}=\begin{bmatrix} 0 & \frac{\delta\mu_2}{A(1+\bar{\bar{m}})^2} \end{bmatrix}, \; B_{21}=\begin{bmatrix} c \\ 0 \end{bmatrix},$$

$$B_{22}=\begin{bmatrix} -\left(1+\mu_1+f+\frac{Af\bar{m}}{c}+\frac{\mu_2}{1+\bar{\bar{m}}}\right)+\frac{\dot{s}}{s} & -\delta \\ \frac{Af\bar{m}}{c} & -f+\frac{\dot{s}}{s} \end{bmatrix}$$

Consider now the norm in R^3 as

$$\left|(u,v,w)\right|=\max\left\{|u|,|v+w|\right\}$$

Where, (u,v,w) denote the vector in and μ denote the Lozinski measure with respect this norm defined. It follows [16]:

$$\mu(B) = \max\{g_1,\ g_2\}$$
$$= \max\{\mu(B_{11}) + |B_{12}|, \mu(B_{22}) + |B_{21}|\}$$

Where,

$$g_1 = -\left(1 + \mu_1 + \frac{Af\overline{m}}{c} + \frac{\mu_2}{1+\overline{m}}\right) + \frac{\dot{s}}{s} + \frac{\delta\mu_2}{A(1+\overline{m})^2},$$

$$g_2 = \frac{\dot{s}}{s} - f + \max\left\{-\left(1 + \mu_1 + \frac{\mu_2}{1+\overline{m}}\right), -\delta\right\} + c$$

If

$$f > c - \max\left\{-\left(1 + \mu_1 + \frac{\mu_2}{1+\overline{m}}\right), -\delta\right\} \qquad (3.8)$$

Conditions hold than there exist a number $w > 0$ such that

$$\mu(B) \le \frac{\dot{s}}{s} - w$$

Hence, $\frac{1}{t}\int_0^t \mu(B)ds \le \frac{1}{t}\frac{\log(s)}{s_0} - w$.

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The Bendixson's criterion given by [17] is thus verified if the conditions given by (38) is true. □

From the above theorems it can be concluded that for the sufficient awareness the disease free equilibrium points remains globally stable and the disease will disappear from the population. It is clear from the equation (3.3) that as the rate ofself motivated awarenessincreases, the basic reproduction decreases. So to control the disease in the population it is necessary to increase the self motivated awareness at the extent so that the basic reproduction number becomes smaller than one.Also if the basic reproduction increases by one then also the self motivated awareness as well as media driven awareness both together contribute in decreasing infected population density.

4. Numerical Simulation

To support the analytical results, numerical simulations have been carried out for various values ofparameters and for different sets of initial conditions. The local and global stability results are verified for a set of values of parameters such that basic reproduction is smaller than one:

$$A = 2.245;\ \mu_1 = 0.979311;\ \mu_2 = 0.7; d_1 = 0.32;\ d_2 = 0.25;\ \tau = 12.5$$

3. CONCLUSION

In this paper, a non-linear mathematical model has been proposed and analyzed to study the effects of awareness on the spread of HIV infection. It has been considered that the growth rate of awareness is proportional to the number of susceptible and also media efforts can contribute to increase the awareness in the population. But increase in the media efforts after some level slowly increase the awareness this can be in corporate by Holling type II function response of media effort on the susceptible population. It has been assumed further that awareness in the susceptible causes some susceptible to isolate themselves from infective. As the awareness increases the basic reproduction number decreases and the disease free equilibrium becomes globally stable.In this case endemic equilibrium point does not exist and infection disappears from the population. But if the basic reproduction number exceeds the unity, the endemic equilibrium pointcomes into existence which remainsglobally stable whenever it exists. The awareness due to media efforts decrease the density of infected population.The self motivatedawareness reduces the basic reproduction number and hence it is concluded that the awareness helps in reducing the spread of the disease.

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