Int. J. Math. And Appl., 7(4)(2019), 53–61
ISSN: 2347-1557
Available Online: http://ijmaa.in/

International Journal of *Mathematics And its Applications*

Modeling the Effects of Targeted Mass Media Campaigns on Alcohol Abuse in Kenya

G. G. Muthuri[1,*] D. M. Malonza[1] and F. Nyabadza[2]

1 Department of Mathematics, Kenyatta University, P.O Box 43844-00100, Nairobi, Kenya.

2 Department of Pure and Applied Mathematics, University of Johannesburg, Auckland Park Campus, Johannesburg, South Africa.

Abstract: Alcoholism causes serious harmful effects to the addicts and the whole community in general. The mass media campaign against alcohol acts as a source of information to halt alcohol abuse and its potentially harmful effects. We developed a deterministic model for alcohol abuse considering the influence of pre-exposure of mass media campaigns against alcohol abuse. We analyzed the local and global stability of the AFE and the endemic equilibrium point of the model. The nature of the bifurcation of the model was analyzed using Center Manifold Theorem. Numerical simulations were carried out to determine where the campaigns should be targeted for effective control of the abuse. The results showed that mass media campaigns against alcohol consumption reduce alcohol abuse in the community. The model was validated using data from rehabilitation centers in Kenya. The results to policymakers imply that the mass media campaign should be regulated to reduce alcohol addiction.

Keywords: Mass mass campaign, alcohol abuse, reproduction number, alcohol-free equilibrium, endemic equilibrium, sensitivity analysis, numerical simulation.

1. Introduction

Alcohol abuse is one of the leading causes of diseases and deaths in young adults and adults throughout the world. There are reports in Kenya of young people whose lives are destroyed because of alcohol. Thirty per cent of Kenyans aged between 15 and 65 years have ever drunk alcohol at some point in their life. 13.3 per cent of Kenyans drink alcohol, which is about four million people according to, [1]. Alcohol is estimated to cause 1.8 million fatalities every year worldwide. When young adults are addicted to alcohol, the country has no future manpower to develop the nation. Researchers like [2] and [3], points out that alcohol and other abused substances may drive irresponsible behaviour among the youth.

Mass media is any means of transmission of information to reach many people. These include broadcast media, digital media, outdoor media, and print media. Examples of broadcast media include videos and music from radio or television. Digital media is communication from the internet which includes email, social media sites like Facebook, Instagram, WhatsApp, Twitter, and my space. The outdoor media include AR-advertising, billboards in towns and on the roadsides, flying billboards, and placards. Print media involve physical objects like books, comics, magazines, newspaper or pamphlets. According to [4], youth who saw more alcohol advertisements on average drank more alcohol and youth in markets with greater alcohol advertising expenditures drunk more. Social media is very important in people's lives because it affects the way they think and what they do. Social media is full of advertisements for alcohol and other drugs. By March 2019, the

* *E-mail: gakii.mwenda@gmail.com*

internet user in Kenya rose to 43.3 million with 83 % internet penetration according to Internet World Statistics (2019). Several researchers have modelled alcohol incorporating mass media. These include [5–8]. The researchers [9] studied the positive and negative role of twitter on alcoholism. They concluded that if the number of negative tweets is decreased would help reduce alcohol abuse, controlling the number of tweets by the moderate drinkers would reduce the alcohol consumption and positive and negative tweets played an important role to the model, although positive tweets played a more vital role than negative tweets.

2. Mathematical Model

2.1. Model formulation

Individuals are recruited into the model at a rate of Λ. Individuals are initiated to alcohol drinking due to contact with the light drinkers at a rate of λ where λ is given by $\beta_1(L+\eta_1 H)$ and β is the effective contact rate of light and heavy drinkers with the non-drinking classes. The rate of dissemination of media awareness of the susceptible is β_m. The human population dies due to natural causes at a rate μ and they die due to alcohol-related causes at a rate δ. The rate of increase of alcohol intake from a few drinks a week to dependence to alcohol is α_1 and light drinkers quit drinking at a rate of α_2. The rate at which heavy drinkers seek treatment or go to rehabilitation centres for treatment is σ_1 and the rate at which heavy drinkers quit drinking without treatment is σ_2. The effective treatment rate of the heavy drinking class is τ_1, which partly due to media awareness. The rate of relapse after rehabilitation back to heavy drinking is τ_2. Individuals relapse only to the heavy drinking class. The rate of the media awareness campaign on the susceptible is represented by θ_1 and θ_2 represents the rate of media awareness programs of the heavy drinking classes which will increase the rate of joining the treatment class. ρ represents the depletion(depreciation) of the media campaigns due to ineffectiveness of the programs or other factors. The rate of effective media campaigns against alcohol is denoted by ω. The efficacy(effectiveness) of the media campaign is measured by ϵ.

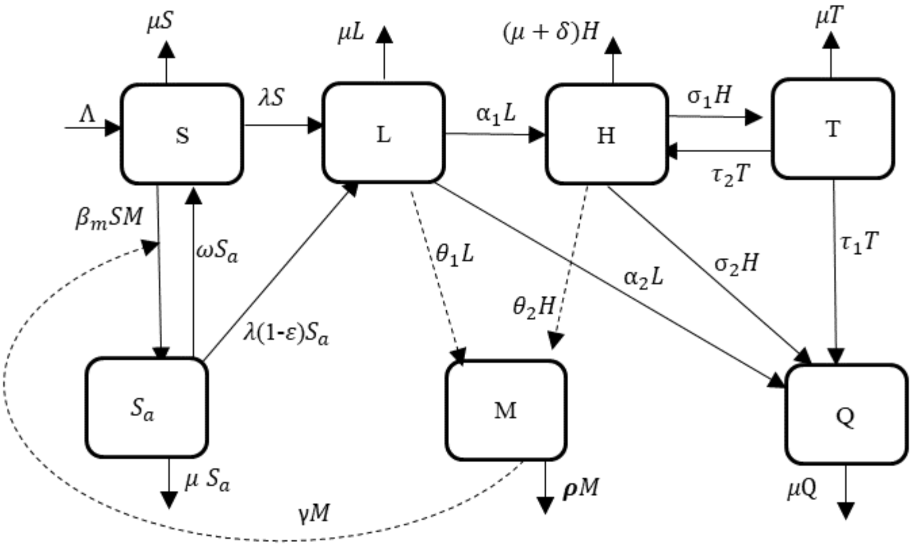


Figure 1: Flow chart of ineffective mass media campaign

From Figure 1, the following non-linear differential equations obtained.

$$\left.\begin{aligned}
\frac{dS}{dt} &= \Lambda + \omega S_a - \beta_m SM - (\lambda + \mu)S, \\
\frac{dS_a}{dt} &= \beta_m SM - (\omega + \mu)S_a - \lambda(1-\epsilon)S_a, \\
\frac{dL}{dt} &= \lambda S + \lambda(1-\epsilon)S_a - (\mu + \alpha_1 + \alpha_2)L, \\
\frac{dH}{dt} &= \alpha_1 L + \tau_2 T - (\mu + \sigma_1 + \sigma_2 + \delta)H, \\
\frac{dT}{dt} &= \sigma_1 H - (\mu + \tau_1 + \tau_2)T, \\
\frac{dQ}{dt} &= \alpha_2 L + \sigma_2 H + \tau_1 T - \mu Q, \\
\frac{dM}{dt} &= \theta_1 L + \theta_2 H - (\rho + \gamma)M,
\end{aligned}\right\} \tag{1}$$

where $\lambda = \beta(L + \eta_1 H)$. To make the mathematical analysis easier and convenient, we introduce the following: $\Phi_1 = \omega + \mu$, $\Phi_2 = 1 - \epsilon$, $\Phi_3 = \mu + \alpha_1 + \alpha_2$, $\Phi_4 = \mu + \sigma_1 + \sigma_2 + \delta$, $\Phi_5 = \mu + \tau_1 + \tau_2$, $\Phi_6 = \rho + \gamma$.

3. Model Analysis

In this section we consider model analysis of model which include: invariant region, positivity of the model, reproduction number of the alcohol abuse, alcohol free equilibrium(AFE),local and global stability of AFE and endemic equilibrium point of the model.

3.1. Invariant Region

Lemma 3.1. *The feasible region Ω_1 is defined by the set*

$$\Omega_1 = \left\{ (S, S_a, L, H, T, Q) \in R^6_+ : 0 \leq N(t) \leq \frac{\Lambda}{\mu} \right\}.$$

with initial data $S > 0, S_a, L > 0, H > 0, T > 0, Q > 0, M > 0$, which is positively invariant for all $t \geq 0$.

Proof. The sum of the human compartments give the total population N, where $N = S + S_a + L + H + T + Q$. Taking the sum of the derivatives we obtain

$$\frac{dN}{dt} = \Lambda - \mu N - \delta H. \tag{2}$$

Since $\delta H \geq 0$ for all $t \geq 0$ equation (2) can be re-written as

$$\frac{dN}{dt} \leq \Lambda - \mu N. \tag{3}$$

Integrating (3) using integrating factor $e^{\mu t}$, we obtain

$$N(t) = \frac{\Lambda}{\mu} + \left(N(0) - \frac{\Lambda}{\mu} \right) e^{-\mu t}. \tag{4}$$

As $t \to \infty$, we get $\limsup_{t \to \infty} N(t) \leq \dfrac{\Lambda}{\mu}$. This, means that the region Ω_1 is attracting all the solutions in $\mathbb{R}^6_+$, which gives the feasible solution set of the model system (1) as

$$\Omega_1 = \left\{ (S, S_a, L, H, T, Q) \in R^6_+ : 0 \leq N(t) \leq \frac{\Lambda}{\mu} \right\}.$$

If $N(0) \leq \frac{\Lambda}{\mu}$, then $N(t) \leq \frac{\Lambda}{\mu}$, as t tends to ∞, and if $N(0) > \frac{\Lambda}{\mu}$, then it implies that either the solution enters Ω_1 in finite time or $N(t)$ approaches $\frac{\Lambda}{\mu}$ asymptotically. Therefore the region Ω_1 is mathematically well-posed and epidemiologically meaningful. In addition, the usual existence, uniqueness and continuation result hold for the model system (1). □

3.2. Positivity of the solutions

Here, we prove that the solutions associated with the state variables remain non-negative for all $t \geq 0$.

Theorem 3.2. *If all parameters of the model system (1) are positive and the initial conditions satisfy*

$$\{(S(0), S_a(0), L(0), H(0), T(0), Q(0), M(0)) \geq 0\} \in \Omega_1,$$

then the solutions set $\{S(t), S_a(t), L(t), H(t), T(t), Q(t), M(t)\}$ of the model system (1) is non-negative for all $t \geq 0$.

Proof. From the first equation of the model system (1), we have

$$\frac{dS}{dt} = \Lambda + \omega S_a - \beta_m SM - (\lambda + \mu)S. \tag{5}$$

$\omega S_a \geq 0$ for all $t \geq 0$ equation (2) can be re-written as

$$\frac{dS}{dt} \leq \Lambda - \zeta S - \mu S, \tag{6}$$

where $\zeta = \lambda + \beta_m M$. The expression in (6) can be written as

$$\frac{d}{dt}\left(S \exp\left\{\int_0^t \zeta(u)du + \mu t\right\}\right) \leq \Lambda \exp\left\{\int_0^t \zeta(u)du + \mu t\right\},$$

Integrating both sides from 0 to t and simplifying, we obtain

$$S(\hat{t}) \leq S(0)\exp\left\{-\int_0^t \zeta(u)du - \mu t\right\} + \exp\left\{-\int_0^t \zeta_v(u)du - \mu\hat{t}\right\} \times \int_0^{\hat{t}} \Lambda \exp\left\{\int_0^x \zeta(x)dx + \mu y\right\} dy > 0. \tag{7}$$

Since, the right-hand side of the expression (7) is always positive, the solution $S(t)$ will always remain positive for all $t > 0$. Using the same argument, it can be shown that the quantities S_a, L, H, T, Q and M are positive for all $t > 0$ [10]. $\square$

4. Equilibrium Points

4.1. Alcohol Free Equilibrium(AFE)

The AFE of the system (1) given by $E_a^0 = \{S^0, S_a^0, L^0, H^0, T^0, Q^0, M^0\}$ refers to the situation when there is no alcohol intake in the population. This implies that $S_a = L = H = T = Q = M = 0$. Thus, the AFE is expressed as

$$E_a^0 = \left\{S^0, S_a^0, L^0, H^0, T^0, Q^0, M^0\right\} = \left\{\frac{\Lambda}{\mu}, 0, 0, 0, 0, 0, 0\right\}. \tag{8}$$

4.2. Alcohol Abuse Reproduction Number

We use the next generation method as described in [11, 12], to find the alcohol abuse reproduction number R_{0a}. The reproduction number R_{0a} is obtained as the dominant eigenvalue of the matrix FV^{-1}, where, F is a matrix representing the occurrence of new infections and V is a matrix that represent transfer of infection, both evaluated at the AFE. These matrices are given as

$$F = \begin{pmatrix} \beta\frac{\Lambda}{\mu} & \beta\frac{\eta_1\Lambda}{\mu} & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \qquad V = \begin{pmatrix} \Phi_3 & 0 & 0 \\ -\alpha_1 & \Phi_4 & -\tau_2 \\ 0 & -\sigma_1 & \Phi_5 \end{pmatrix}. \tag{9}$$

Therefore the alcohol abuse reproduction number R_{0a} is given by;

$$R_{0a} = \frac{\beta\Lambda(\Phi_4(1-\Psi_1)+\alpha_1\eta_1)}{\Phi_3\Phi_4\mu(1-\Psi_1)}, \text{ where } \Psi_1 = \frac{\sigma_1\tau_2}{\Phi_4\Phi_5}. \tag{10}$$

From (10), Ψ_1 refers to the proportion of individuals who move from H to T and back. On the other hand $(1-\Psi_1)$ are the individuals who do not cycle between the two compartments. From Theorem 2 of [12], the following result is obtained.

Theorem 4.1. *The AFE point* (E_a^0) *is locally asymptotically stable if* $R_{0a} < 1$ *and unstable if* $R_{0a} > 1$.

Proof. To prove the theorem, we obtain the Jacobian matrix of the system (1) at E_a^0 to obtain

$$J_{E_a^0} = \begin{pmatrix} -\mu & \omega & \frac{-\Lambda\beta}{\mu} & \frac{-\Lambda\beta\eta_1}{\mu} & 0 & 0 & \frac{-\beta_m\Lambda}{\mu} \\ 0 & -\Phi_1 & 0 & 0 & 0 & 0 & \frac{\beta_m\Lambda}{\mu} \\ 0 & 0 & \frac{\beta\Lambda}{\mu}-\Phi_3 & \frac{\beta\eta_1\Lambda}{\mu} & 0 & 0 & 0 \\ 0 & 0 & \alpha_1 & -\Phi_4 & \tau_2 & 0 & 0 \\ 0 & 0 & 0 & \sigma_1 & -\Phi_5 & 0 & 0 \\ 0 & 0 & \alpha_2 & \sigma_2 & \tau_1 & -\mu & 0 \\ 0 & 0 & \theta_1 & \theta_2 & 0 & 0 & -\Phi_6 \end{pmatrix} \tag{11}$$

From (11) it can easily be seen that $-\mu$ and $-\Phi_1, -\mu, -\Phi_6$ are the first four eigenvalues which have negative real parts. The remaining eigenvalues are obtained from the following reduced matrix in (12).

$$J_{E_a^0} = \begin{pmatrix} \frac{\beta\Lambda}{\mu}-\Phi_3 & \frac{\beta\eta_1\Lambda}{\mu} & 0 \\ \alpha_1 & -\Phi_4 & \tau_2 \\ 0 & \sigma_1 & -\Phi_5 \end{pmatrix} \tag{12}$$

The characteristic polynomial of (12) is given by

$$y(\nu) = \nu^3 + a_1\nu^2 + a_2\nu + a_3, \tag{13}$$

where

$$a_1 = \Phi_3+\Phi_4+\Phi_5-\frac{\beta\Lambda}{\mu}, \quad a_2 = \Phi_4\Phi_5(1-\Psi_1)+\Phi_3(\Phi_4+\Phi_5)-\frac{\beta\Lambda}{\mu}(\alpha_1\eta_1+\Phi_4+\Phi_5), \quad a_3 = \Phi_3\Phi_4\Phi_5[1-R_0].$$

We then use Routh-Hurwitz criterion to establish the necessary and sufficient conditions for all the roots of $y(\nu)$ to have negative real parts. The Routh-Hurwitz criterion of stability of the AFE is given by

$$\begin{cases} H_1 > 0 \\ H_2 > 0 \\ H_3 > 0 \end{cases} \Longleftrightarrow \begin{cases} H_1 > 0 \\ H_2 > 0 \\ H_3 > 0 \end{cases},$$

where

$$H_1 = a_1, \quad H_2 = \begin{vmatrix} a_1 & 1 \\ a_3 & a_2 \end{vmatrix}, \quad H_3 = \begin{vmatrix} a_1 & 1 & 0 \\ a_3 & a_2 & a_1 \\ 0 & 0 & a_3 \end{vmatrix}.$$

We then have

$$
\begin{aligned}
&H_1 = a_1 = \Phi_3 + \Phi_4 + \Phi_5 - \frac{\beta\Lambda}{\mu} > 0,\\
&H_2 = a_1a_2 - a_3 = \left(\Phi_3 + \Phi_4 + \Phi_5 - \frac{\beta\Lambda}{\mu}\right)\left(\Phi_4\Phi_5\left(1-\Psi_1\right) + \Phi_3\left(\Phi_4 + \Phi_5\right) - \frac{\beta\Lambda\left(\alpha_1\eta_1 + \Phi_4 + \Phi_5\right)}{\mu}\right) - \left(1 - R_0\right)\Phi_3\Phi_4\Phi_5 > 0,\\
&H_3 = a_1a_2a_3 - a_3^2 = \left(1 - R_0\right)\Phi_3\Phi_4\Phi_5\Bigg(\left(\Phi_3 + \Phi_4 + \Phi_5 - \frac{\beta\Lambda}{\mu}\right)\\
&\qquad\left(\Phi_4\Phi_5\left(1-\Psi_1\right) + \Phi_3\left(\Phi_4 + \Phi_5\right) - \frac{\beta\Lambda\left(\alpha_1\eta_1 + \Phi_4 + \Phi_5\right)}{\mu}\right) - \left(1 - R_0\right)\Phi_3\Phi_4\Phi_5\Bigg) > 0.
\end{aligned}
$$

The above result shows that we always have $H_1 > 0, H_2 > 0$ and $H_3 > 0$ if and only if $R_{0a} < 1$. Therefore we conclude that the AFE is locally asymptotically stable whenever $R_{0a} < 1$. □

4.3. Existence of Endemic equlibrium points(EEP)

Endemic equilibrium of our model occurs when alcohol persists in the community. This equilibrium is denoted by $E_a^* = \{S^*, S_a^*, L^*, H^*, T^*, Q^*, M^*\}$. To obtain E_a^*, we equate the RHS of system (1) to zero and solve in terms of L^* to obtain

$$
\left.
\begin{aligned}
&S^* = \frac{\omega S_a^* + \Lambda}{\beta\eta_1 H^* + \mu + \beta L^* + \beta_m M^*}, \quad H^* = \frac{\alpha_1 L^* + \tau_2 T^*}{\Phi_3}, \quad T^* = \frac{\alpha_1 L^* \sigma_1}{\Phi_3\Phi_4(1-\Psi_1)},\\
&S_a^* = \frac{\Lambda\beta_m M^*}{\left(\beta\eta_1 H^* + \mu + \beta L^*\right)\left(\beta\Phi_2\left(\eta_1 H^* + L^*\right) + \Phi_1\right) + M^*\beta_m\left(\beta\Phi_2\left(\eta_1 H^* + L^*\right) + \Phi_1 - \omega\right)},\\
&Q^* = \frac{L^*\left(\alpha_1\left(\sigma_1\tau_1 + \sigma_2\Phi_4\right) + \Phi_3\Phi_4\alpha_2\left(1-\Psi_1\right)\right)}{\Phi_3\Phi_4\mu\left(1-\Psi_1\right)}, \quad M^* = \frac{L^*(\Phi_4(\theta_1\Phi_3(1-\Psi_1) + \alpha_1\theta_2))}{\Phi_3\Phi_4\Phi_5\left(1-\Psi_1\right)}.
\end{aligned}
\right\}
\tag{14}
$$

Substituting the solutions of the state variables in (14) into the third equation of (1) we get

$$
A_2 L^{*2} + A_1 L^* + A_0 = 0, \tag{15}
$$

where,

$$
\left.
\begin{aligned}
A_2 &= \beta\Phi_2\Phi_6(\Phi_4(\Phi_3(1-\Psi_1) + \alpha_1\eta_1))(\beta\Phi_5(\Phi_4(\Phi_3(1-\Psi_1) + \alpha_1\eta_1)) + \beta_m(\Phi_4(\theta_1\Phi_3(1-\Psi_1) + \alpha_1\theta_2))),\\
A_1 &= -[\beta_m(\Phi_1 - \omega)(\Phi_4(\alpha_1\theta_2 + \Phi_3\theta_1(1-\Psi_1))) + \beta\Phi_5(\mu\Phi_2 + \Phi_1)(\Phi_4(\alpha_1\eta_1 + \Phi_3(1-\Psi_1))]\\
&\quad + \mu\Phi_2 R_0(\beta\Phi_5(\Phi_4(\alpha_1\eta_1 + \Phi_3(1-\Psi_1)) + \beta_m(\Phi_4(\alpha_1\theta_2 + \theta_1\Phi_3(1-\Psi_1)))),\\
A_0 &= \mu\Phi_1\Phi_5\Phi_6\Phi_3^2\Phi_4^2\left(1-\Psi_1\right)^2(1-R_0).
\end{aligned}
\right\}
$$

Note that A_2 is positive, and that A_1 may be rearranged as:

$$
A_1 = \left[\frac{\mu\Phi_2 R_0(\beta\Phi_5(\Phi_4(\alpha_1\eta_1 + \Phi_3(1-\Psi_1)) + \beta_m(\Phi_4(\alpha_1\theta_2 + \theta_1\Phi_3(1-\Psi_1))))}{\beta_m(\Phi_1 - \omega)(\Phi_4(\alpha_1\theta_2 + \Phi_3\theta_1(1-\Psi_1))) + \beta\Phi_5(\mu\Phi_2 + \Phi_1)(\Phi_4(\alpha_1\eta_1 + \Phi_3(1-\Psi_1))} - 1\right].
$$

It follows that:

(i) There is a unique endemic equilibrium if $A_0 < 0$ (i.e. if $R_0 > 1$);

(ii) There is a unique endemic equilibrium if $A_1 < 0$; and $A_0 = 0$; or $A_1^2 - 4A_2A_0 = 0$;

(iii) There are two endemic equilibria if $A_0 > 0$; $A_1 < 0$ and $A_1^2 - 4A_2A_0 > 0$;

(iv) There are no endemic equilibria otherwise.

Note that the hypothesis $A_0 > 0$ is equivalent to $R_0 < 1$, and the hypothesis $A_1 < 0$ is equivalent to $R_0 > R_c$, where

$$R_c = \left[1 - \frac{A_1^2}{4A_2\mu\Phi_1\Phi_3^2\Phi_4^2\Phi_5\Phi_6\left(1-\Psi_1\right)^2}\right].$$

The results of this section may be summarized in the following:

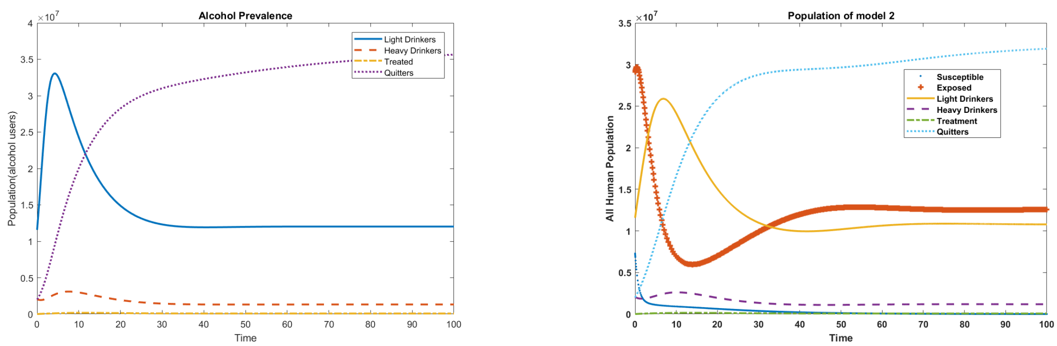
Theorem 4.2. *If $R_{0a} < 1$, then E_0 is an equilibrium of system (1) and it is locally asymptotically stable. Furthermore, there exists an endemic equilibrium if conditions in item (ii) are satisfied, or two endemic equilibria if conditions in item (iii) are satisfied. If $R_{0a} > 1$, then E_0 is unstable and there exists a unique endemic equilibrium.*

5. Numerical Simulations

We carried out numerical simulation of the model using the initial conditions: $S = 7.28X10^6, S_a = 2.91X10^7, L = 11.57X10^7, H = 2.028X10^6, T = 2.0X10^3, Q = 2.0X10^6$. Table 1 gives the parameters used in the model, their values, description and the source.

Parameter	Description	Value	Source
Λ	Recruitment rate of drinkers into population	1674000	[13]
μ	Natural death rate	0.025	Assumed
β	Effective contact rate	0.00000002	[7]
β_m	Rate of dissemination of media awareness	0.00005	Assumed
α_1	Transfer rate of light drinkers to heavy drinkers	0.031	Assumed
α_2	Rate of quitting alcohol of the light drinkers	0.07	Assumed
σ_1	Treatment rate of the heavy drinkers	0-0.09	Assumed
σ_2	Rate of heavy drinkers quitting the alcohol	0.05	Assumed
τ_1	Rate of effective treatment	0.1	Assumed
τ_2	Rate of relapse back to heavy drinking	0.2	Assumed
δ	Death rate due to alcohol abuse	0.2	Assumed
θ_1	Rate of awareness programs on the Susceptible	0.0005	[7]
θ_2	Rate of awareness programs on the heavy drinkers	0.0001	Assumed
ρ	Rate of depletion of media programs	0.06	[7]
ω	Rate of effective media campaign	0.0002	Assumed
η_1	Modification parameter	0.01	Assumed
ϵ	Efficacy of media Campaign	0-1	Assumed

Table 1: Parameter Description and their Values

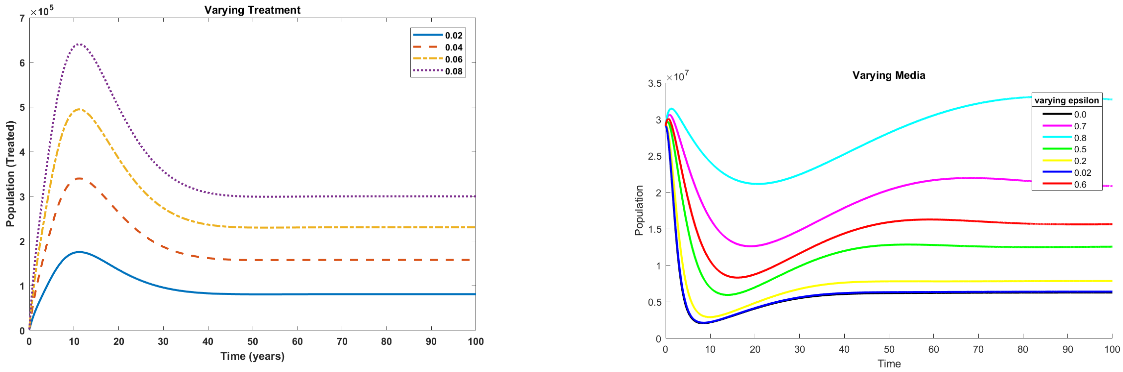


(a) Alcohol prevalence

(b) All the population classes

Figure 2: Alcohol classes

Figure 2a represent the individuals who have ever taken alcohol at any time in their life time. The quitters class increase with time since individuals move from all other classes to quitters class. The light drinkers class increase in the first years but later decrease because some individuals go for treatment and other quit alcohol. The least populated class is the treatment class because few heavy drinkers go for treatment. Figure 2b represent all the relationship between the population classes in our model. The number of people in the treatment class is very small compared to the number in the other classes. The susceptible individuals decreased with time as they join the exposed to media campaign class and then move to light drinking class.



(a) Alcohol prevalence

(b) All the population classes

Figure 3: Varying Treatment and Media

Figure 3a shows varying treatment rate from 0 to 0.09. As the treatment rate increases, the number of individuals in the treatment class increases. When the rate of treatment is zero, the number of individuals in the treatment class remain constant. Figure 3b shows how mass media dissemination varies with time from 0.2 to o.7. As the rate increases, the populations exposed to media increases. This shows that there will be less people joining the alcoholic classes as we increase media awareness.

6. Conclusions

In section 3, ths study considered the invariant region of the model and it was established that the model is well posed and epidemiological meaningful. We proved the positivity of the solutions and we shown that the solutions are always positive for all time $t > 0$. In section 4, we used the Routh-Hurwitz Criterion to show that AFE of the model is locally asymptotically stable whenever $R_{0a} < 1$. We also shown the conditions for the existence of the EEP. Section 5 involved the numerical simulation of the model parameters. We concluded that as the rate of treatment and mass media campaign increases, the population in the alcohol classes decreases, hence treatment and mass media campaign can be used to reduce alcohol consumption in the community.

In Kenya, most of mass media campaign are geared towards marketing alcohol consumption. We recommend reduction of the campaign towards alcohol consumption and the Kenyan government should encourage all mass media campaign against alcohol abuse. This will to a great extent reduce alcohol consumption.

References

[1] W. H. O, *Management of Substance Abuse Unit*, World Health Organization, (2014).

[2] G. S. Eshiwani, *Education in Kenya since independence*, East African Publishers, (1993).

[3] J. W. Khamasi and W. Mutia, *Sexuality in the media report: implications for educational leadership*, Paper presentation at Kenya Association of Educational administration and management, (2007).

[4] L. B. Snyder, Frances Fleming Milici, Michael Slater, Helen Sun and Yuliya Strizhakova, *Effects of alcohol advertising exposure on drinking among youth*, Archives of pediatrics & adolescent medicine, American Medical Association, 160(2006), 18-24.

[5] Ridouan Bani, Rasheed Hameed, Steve Szymanowski, Priscilla Greenwood, Christopher Kribs-Zaleta and Anuj Mubayi, *Influence of environmental factors on college alcohol drinking patterns*, Math. Bio. & Eng., 10(2013), 1281-1300.

[6] Hai-Feng Huo and Yan-Yan Wang, *Impact of media coverage on the drinking dynamics in the scale-free network*, Springer Plus, 5(2016), 204.

[7] A. K. Misra, Anupama Sharma and J. B. Shukla, *Modeling and analysis of effects of awareness programs by media on the spread of infectious diseases*, Maths and Comp. Modelling. Elsevier, 53(2011), 1221-1228.

[8] Balram Dubey, Preeti Dubey and Uma S. Dubey, *Role of media and treatment on an SIR model*, Nonlinear Anal. Model. Control., 21(2016), 185-200.

[9] Hai-Feng Huo and Xiang-Ming Zhang, *Complex dynamics in an alcoholism model with the impact of Twitter*, Mathematical Bio., 281(2016), 24-35.

[10] Ashrafi M Niger and Abba B. Gumel, *Mathematical analysis of the role of repeated exposure on malaria transmission dynamics*, Differential Equations and Dynamical Systems, 16(2008), 251-287.

[11] Carlos Castillo-Chavez, Zhilan Feng and Wenzhang Huang, *On the computation of ro and its role on Mathematical approaches for emerging and reemerging infectious diseases: an introduction*, Springer, 1(2002), 229.

[12] P. Van den Driessche, *Reproduction numbers of infectious disease models*, Infectious Disease Modelling, 2(2017), 288-303.

[13] KKNB, Statistics, *Kenya 2009 population and housing census highlights*, KKNB Statistics, (2010).