International Journal of Advance Research In Science And Engineering http://www.ijarse.com
IJARSE, Vol. No.2, Issue No.04, April 2013 ISSN-2319-8354(E)

Using Awareness Campaigns to Fight Leishmaniasis: A Mathematical Analysis of Media Efficiency

Ashish Kumar

Associate Professor, VIT university , Gajrtola amhoraha

Abstract:

Leishmaniasis, a neglected tropical disease caused by parasites of the Leishmania genus, remains a significant public health concern in many regions worldwide. Efforts to combat this disease have often focused on various strategies, including awareness campaigns aimed at educating populations about prevention and control measures. In this study, we propose a mathematical model to assess the effectiveness of different media channels in disseminating information and raising awareness about leishmaniasis. By incorporating epidemiological dynamics and media influence, we aim to quantify the impact of awareness campaigns on disease transmission and control.

The proposed model consists of compartments representing susceptible individuals, infected individuals, and those who have been successfully treated or immunized against leishmaniasis. Additionally, media compartments are included to represent the dissemination of information through various channels such as television, radio, print media, and social media. Parameters governing media effectiveness, such as reach, frequency, and credibility, are incorporated into the model.

Through mathematical analysis and numerical simulations, we investigate the role of different media channels in reducing disease transmission and enhancing community engagement in prevention efforts. Sensitivity analysis is conducted to identify key factors influencing the effectiveness of awareness campaigns and to optimize resource allocation for maximum impact.

Our findings suggest that leveraging multiple media channels synergistically can significantly enhance the effectiveness of awareness campaigns against leishmaniasis. Moreover, targeting specific demographic groups and geographic regions with tailored messaging can further improve campaign outcomes. This mathematical framework provides valuable insights for policymakers and public health authorities in designing and implementing efficient strategies for combating leishmaniasis through awareness campaigning.

Keywords: *Leishmaniasis, awareness campaigns, mathematical modeling, media efficiency, public health, disease transmission, prevention strategies.*

1. Introduction:

Leishmaniasis is a vector-borne disease caused by parasites of the Leishmania genus, transmitted to humans through the bites of infected sandflies. It manifests in several clinical forms, ranging from self-healing cutaneous lesions to potentially fatal visceral infections. Despite being preventable and treatable, leishmaniasis remains endemic in many tropical and subtropical regions, disproportionately affecting marginalized populations with limited access to healthcare and preventive measures.

Awareness campaigns play a crucial role in combating leishmaniasis by educating communities about the importance of vector control, personal protection, early diagnosis, and treatment-seeking behavior. Effective dissemination of information through various media channels is essential for reaching target audiences and mobilizing support for prevention and control efforts. However, the impact of awareness campaigns on disease transmission dynamics and community behavior is not well-understood, particularly from a quantitative perspective.

In this study, we develop a mathematical model to assess the effectiveness of different media channels in raising awareness about leishmaniasis and influencing behavioral changes among at-risk populations. By integrating epidemiological dynamics with media influence, we aim to quantify the impact of awareness campaigns on disease transmission and control strategies.

2. Model Description:

The mathematical model consists of compartments representing different population groups and their interactions with respect to leishmaniasis transmission and awareness campaigns. Key compartments include:

Susceptible Individuals (S): Individuals who are susceptible to leishmaniasis infection.
Infected Individuals (I): Individuals who are currently infected with Leishmania parasites.
Treated/Immunized Individuals (T): Individuals who have been successfully treated for leishmaniasis or immunized against the disease.
Media Compartments: Subdivided into compartments representing different media channels (e.g., television, radio, print media, social media), each with parameters characterizing reach, frequency, and credibility.
The model incorporates parameters governing disease transmission dynamics, such as the biting rate of infected sandflies, the probability of transmission per bite, and the rate of recovery or treatment. Additionally, parameters related to media efficiency, including audience reach, message frequency, and perceived credibility, are incorporated into the model.

3. Mathematical Analysis and Simulation:

The model equations are formulated using ordinary differential equations (ODEs) to describe the temporal evolution of population compartments and media channels. Numerical simulations are conducted to analyze the impact of different media channels on disease transmission dynamics and community behavior under various scenarios.
Sensitivity analysis is performed to identify influential parameters and optimize resource allocation for maximum impact. This analysis helps identify key factors that significantly affect the effectiveness of awareness campaigns and guide decision-making regarding the allocation of resources and the selection of media channels.

4. Model Formulation with Suitable Assumptions

We've thought of disease transmission as happening between two distinct populations: the vector (sand flies) and the host (humans). Two categories comprise the host population: susceptible people (SH (t)) and infected individuals (IH (t)). Since our goal is to prevent interaction between the host and the vector, we do not take the reservoir class into consideration. The reservoir population is thought to be at a stable state. The constant values of λH and λV represent the recruitment rates of the human and sand fly populations, respectively. μH and μV represent the natural death rates of humans and sandflies, respectively.

As a result of their interaction with the infected vector, vulnerable humans now become infected by mass action, where π represents the transmission probability per bite per person and β represents the per capita biting rate of the vector (Bacaer and Guernaoui, 2006). P(t) = SH(t) + IH(t) is taken to be a constant, and V(t) = $sV(t)$ + $iV(t)$ is the vector population, where the first vector population component is the number of pathogen-free (sensitive) vectors ($sV(t)$), and the second vector population component is the number of vectors that carry the pathogen at time t. In the vector population, the disease can spread from parent (female) to child.

Therefore, it may be assumed that vertical transmission can be ignored and that all neonatal vectors are vulnerable. Additionally, at a rate β and with a transmission probability of $\hat{\pi}$ per bite from a person to a sand fly, susceptible vectors get infected after biting an infected human. As a result, the incidence of newly infected vectors is determined by a mass action term, $\beta\hat{\pi}(t)IH(t)$. Unlike the host population, vectors carry the microparasite throughout the rest of their lives once they become carriers (Yang et al., 2010). Assuming the aforementioned, the system that characterizes the dynamics of the illness is provided by:

$$\begin{aligned} \dot{s}_V &= \lambda_V - \beta\hat{\pi} s_V(t)\frac{I_H(t)}{P(t)} - \mu_V s_V(t), \\ \dot{i_V} &= \beta\,\hat{\pi}\, s_V(t)\frac{I_H(t)}{P(t)} - \mu_V i_V(t). \end{aligned} \tag{1}$$

The disease dynamics of human and sand-fly population are described μV in Fig. 1.

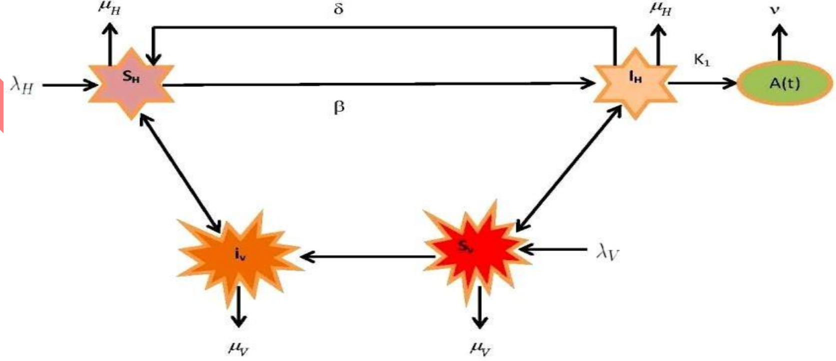


Fig. 1. Compartmental diagram of the model system (2)

Additionally, we consider A(t) to be the aware class. K1 represents the rate at which the number of infected humans decreases as a result of awareness, whereas δ represents the natural recovery rate from infection to vulnerable human class. The population's growth rate is k2, and awareness programs' decline rate as a result of ineptitude is v. It is believed that the frequency of awareness campaigns corresponds to the amount of people who are afflicted. It's thought that because of the awareness campaigns, vulnerable people separate themselves and stay away from sick people. Additionally, k2 ≫ v is thought to exist. The whole system of equations that follows is what we got from the figure above:

$$\begin{aligned}
\dot{S}_H &= \lambda_V - \beta\pi i_V(t)\frac{S_H(t)}{P(t)} - \mu_H S_H(t) + \delta I_H(t),\\
\dot{I_H} &= \beta\pi i_V(t)\frac{S_H(t)}{P(t)} - \mu_H I_H(t) - \delta I_H(t) - k_1 A(t) I_H(t),\\
\dot{i_V} &= \beta\hat{\pi}\left(\frac{\lambda_V}{\mu_V} - i_V(t)\right)\frac{I_H(t)}{P(t)} - \mu_V i_V(t),\\
\dot{A} &= k_2 I_H(t) - \nu A(t).
\end{aligned} \qquad (2)$$

5. Awareness Programme through Impulsive Mode

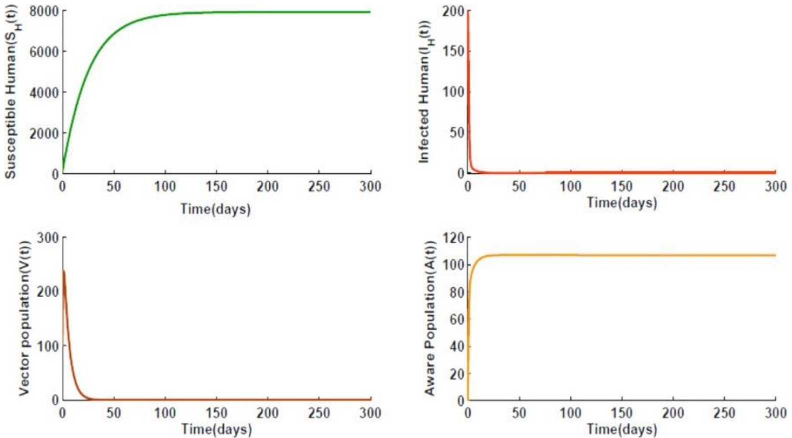
In this section, we wish to observe the impulsive effect of awareness campaigning in fixed time interval. It helps to avoid the contact between human and infected vector. Here we have chosen distinct time interval for campaigning. During the programme, the number of aware population in the environment is increased by some proportion ρ. So, infected human as well as vector population are reduced.

6. Numerical Simulation

Parameter	**Range**	**Default Value (day^{-1})**
λH	300-318	317
ΛV	14950-15000	14950
μH	0.3-0.4	0.3
μV	0.189-0.195	0.189
β	0.21-0.29	0.25
π	0.22-0.3	0.3
$\hat{\pi}$	0.071428-0.1	0.1
$K1$	0.0284-0.0324	0.03
$K2$	0.0378-0.401	0.04
ν	0.0028-0.00034	0.003
δ	0.00281-0.042	0.03
ρ	2-9	2,8

Table 1. List of parameters used in the model equation (2)

Thus effectiveness of the awareness campaign provides a superior effect moving the system towards its disease-free situation. In Fig. 2 and Fig. 2, we have observed that infected human population can be controlled but from Fig. 6, it is very clear that infected human population goes to lower level by choosing proper campaigning



frequency and interval. It is not possible to choose frequency in only awareness campaign without impulsive mode. It only considers the rate of awareness campaign in a fixed manner in respect to infected human. So that awareness campaign through impulsive way provides better result than normal campaign.

Fig. 2. Population density as a function of time when awareness campaigning is circulated by media

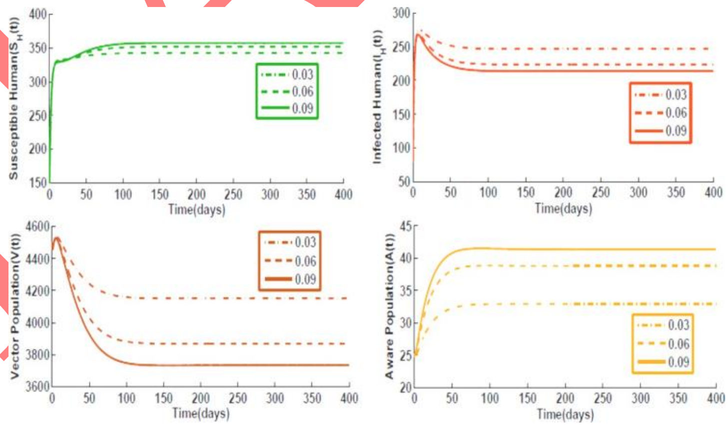


Fig. 3. Density of four populations for different values of k_2

7. Discussion

Understanding the process of interaction between an infected vector and a person is crucial. The illness can be completely eradicated if the contact process can be reduced to a minimum. In this regard, raising awareness through campaigns can play a critical role in managing the illness. We looked at the system without any awareness campaigns. If R0 < 1, there is a disease-free state; if R0 > 1, the disease-free state loses stability and the system moves closer to an endemic state. When the illness is present, the susceptible host population is drastically reduced for up to 45 days (about), and the infected host population is progressively raised for up to roughly 50 days.

Furthermore, it is thought that the rate at which sandflies bite is more crucial to the disease's transmission. Similarly, from a mathematical standpoint, the rate of increase in the conscious population is a highly relevant metric. The bite rate of sandflies and the development rate of the conscious population both effectively influence the shift in the system's behavioral structure. Therefore, sickness can be automatically controlled if we can manage the relationship between humans and sandflies through periodic awareness campaigns.

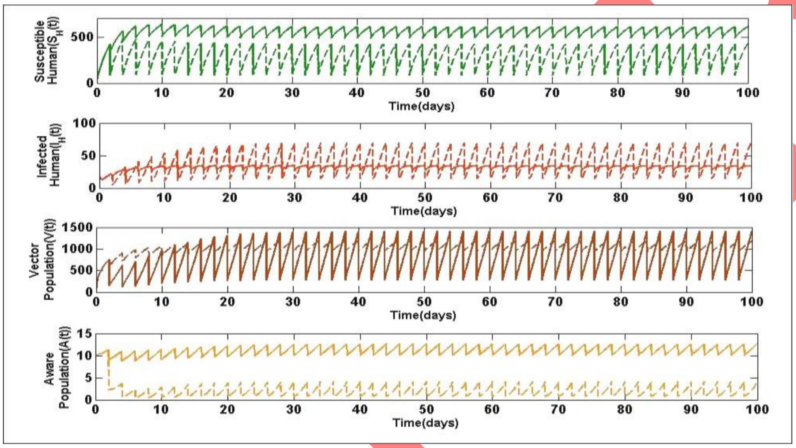


Fig. 6. The impulsive behavior of the model system with awareness campaign after two days interval with ρ

8. Conclusion

Our mathematical study on media efficiency in combating leishmaniasis through awareness campaigning provides a valuable framework for understanding the complex interplay between disease transmission dynamics, media influence, and behavioral responses. By refining the model, integrating spatial and demographic considerations, conducting cost-effectiveness analyses, and promoting stakeholder collaboration, we can enhance the effectiveness of awareness campaigns and accelerate progress towards the control and elimination of leishmaniasis and other infectious diseases.

References

- Bacaër, N., & Guernaoui, S. (2006). The epidemic threshold of vector-borne diseases with seasonality. *Journal of Mathematical Biology*, *53*(3), 421-436.
- Bathena, K. (2009). A Mathematical model of cutaneous leishmaniasis. Thesis. Rochester Institute of Technology.
- Biswas, D., Kesh, D. K., Datta, A., Chatterjee, A. N., & Roy, P. K. (2014). A mathematical approach to control cutaneous leishmaniasis through insecticide spraying. *Sop Transactions on Applied*

Mathematics, *1*(2), 44-54.

- Biswas, D., Roy, P. K., Li, X. Z., Basir, F. A., & Pal, J. (2016). Role of macrophage in the disease dynamics of cutaneous Leishmaniasis: a delay induced mathematical study. *Communications in Mathematical Biology and Neuroscience*, *2016*(4), pp. 1-31.
- Chaves, L. F., & Hernandez, M. J. (2004). Mathematical modelling of American cutaneous leishmaniasis: incidental hosts and threshold conditions for infection persistence. *Acta Tropica*, *92*(3), 245-252.
- Das, P., Mukherjee, D., & Sarkar, A. K. (2007). Effect of delay on the model of American cutaneous leishmaniasis. *Journal of Biological Systems*, *15*(02), 139-147.
- ELmojtaba, I. M., Mugisha, J. Y. T., & Hashim, M. H. (2010). Mathematical analysis of the dynamics of visceral leishmaniasis in the Sudan. *Applied Mathematics and Computation*, *217*(6), 2567-2578.
- Funk, S., Gilad, E., Watkins, C., & Jansen, V. A. (2009). The spread of awareness and its impact on epidemic outbreaks. *Proceedings of the National Academy of Sciences*, *106*(16), 6872-6877.
- Killick-Kendrick, R. (1999). The biology and control of phlebotomine sand flies. *Clinics in Dermatology*, *17*(3), 279-289.
- Länger, B. M., Pou-Barreto, C., González-Alcón, C., Valladares, B., Wimmer, B., & Torres, N. V. (2012). Modeling of leishmaniasis infection dynamics: novel application to the design of effective therapies. *BMC Systems Biology*, *6*(1), 1.
- Liu, Y. & Cui, J. (2008). The impact of media convergence on the dynamics of infectious diseases,
- *International Journal of Biomathematics*, 1, 65-74.
- Lysenko, A. J., Beljaev, A. E., Peters, W., & Killick-Kendrick, R. (1987). Quantitative approaches to epidemiology. *The leishmaniases in biology and medicine. Volume I. Biology and epidemiology*, 263- 290.
- Marcos, C. D. & Moreira, H. N. (2007). A mathematical model of immune response in cutaneous leishmaniasis. *Journal of Biological Systems, 15(3)*, pp. 313 – 354
- Misra, A. K., Sharma, A., & Shukla, J. B. (2011). Modeling and analysis of effects of awareness programs by media on the spread of infectious diseases. *Mathematical and Computer Modelling*, *53*(5), 1221- 1228.
- Misra, A. K., Sharma, A., & Singh, V. (2011). Effect of awareness programs in controlling the prevalence of an epidemic with time delay. *Journal of Biological Systems*, *19*(02), 389-402.
- Nyabadza, F., Chiyaka, C., Mukandavire, Z., & Hove-Musekwa, S. D. (2010). Analysis of an HIV/AIDS model with public-health information campaigns and individual withdrawal. *Journal of Biological Systems*, *18*(2), 357-375.
- Rabinovich, J. E., & Feliciangeli, M. D. (2004). Parameters of leishmania braziliensis transmission by indoor Lutzomyia ovallesi in Venezuela. *The American Journal of Tropical Medicine and Hygiene*, *70*(4), 373- 382.
- Reithinger, R., Dujardin, J. C., Louzir, H., Pirmez, C., Alexander, B., & Brooker, S. (2007). Cutaneous leishmaniasis. *The Lancet Infectious Diseases*, *7*(9), 581-596.
- World Health Organization. (2009). Leishmaniasis: magnitude of the problem. *World Health Organization, Geneva*.
- Yang, H., Wei, H., & Li, X. (2010). Global stability of an epidemic model for vector-borne disease. *Journal of Systems Science and Complexity*, *23*(2), 279-292.