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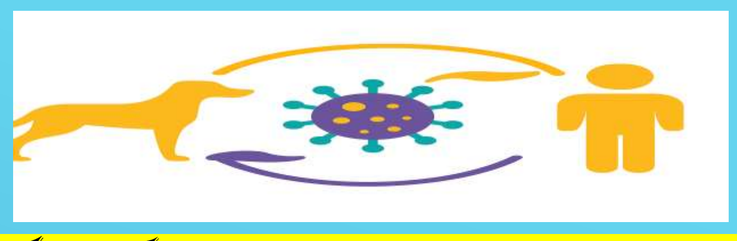


MODELLING RABIES TRANSMISSION WITH VACCINATION: INCORPORATING PHARMACEUTICAL AND PARTICLE PROCESSING FOR PRE-EXPOSURE PROPHYLAXIS OPTIMIZATION

K. Anjali[1] *, T. Nandha Gopal[1], T. Megala[1], A. Ashwin[1], and A. Yasotha[2]

•[1] Department of Mathematics, Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Periyanaickenpalayam, Coimbatore, Tamil Nadu 641 020, India

•[2] Department of Mathematics, United Institute of Technology, Periyanaickenpalayam, Coimbatore, Tamil Nadu 641 020, India

*Corresponding author : kanjaliphd@gmail.com

INTRODUCTION

- Rabies remains a persistent **zoonotic disease**, mainly transmitted from **domestic dogs to humans**.
- Traditional rabies models focus on transmission and static vaccination, **ignoring vaccine formulation and delivery mechanisms**.
- **RESEARCH GAP:** Lack of integration between **pharmaceutical technology** and **epidemiological modeling**.

AIM

- **OBJECTIVES**
- To incorporate pharmaceutical and particle engineering parameters—such as encapsulation, stability enhancement, and controlled release—into the vaccination process.
- To analyze stability, boundedness, and disease elimination thresholds.

MODEL EQUATION

Dog to dog transmission

$$\begin{cases} \frac{dS_d}{dt} = \Lambda \frac{\beta_{dd} l S_d I_d}{1 + a_{dd} l S_d b_{dd} I_d} - \upsilon_d E_d S_d \\ \frac{dV_d}{dt} = \upsilon_d E_d S_h^{\text{stab}} R_h S_h - \mu_h V_d \\ \frac{dI_d}{dt} = \frac{\beta_{dd} l S_h I_d}{1 + a_{dd} S_d + b_{dd} I_d} - \alpha_d I_d \end{cases}$$

Dog to human transmission

$$\begin{cases} \frac{dS_h}{dt} = \Lambda \frac{\beta_{dh} h S_h I_d}{1 + a_{dd} l S_d b_{dh} I_d} - \upsilon_h E_h R_h S_h \\ \frac{dV_h}{dt} = \upsilon_h E_h S_h^{\text{stab}} R_h S_h - \mu_h V_h \\ \frac{dI_h}{dt} = \frac{\beta_{dh} h S_h I_d}{1 + a_{dh} S_d + b_{dh} I_d} - a_h I_h \end{cases}$$

POSITIVITY AND BOUNDEDNESS

$$\frac{dS_d}{dt} = \Lambda_d \geq 0 (Since\ all\ the\ terms\ under\ S_d\ vanish);$$

$$\frac{dV_d}{dt} = 0 (Since\ all\ the\ terms\ under\ V_d\ vanish);$$

$$\frac{dI_d}{dt} = \frac{\beta_{dd} S_d I_d}{1 + a_{dd} S_d + b_{dd} I_d} \geq 0 (Since S_d, I_d \geq 0);$$

$$\frac{dS_h}{dt} = \Lambda_h \geq 0 (Since\ all\ the\ terms\ under\ S_h\ vanish);$$

$$\frac{dV_h}{dt} = 0 (Since\ all\ the\ terms\ under\ V_h\ vanish);$$

$$\frac{dI_h}{dt} = \frac{\beta_{dh} S_h I_d}{1 + a_{dh} S_d + b_{dh} I_d} \geq 0 (Since\ S_h, I_h \geq 0);$$

EQUILIBRIUM POINTS

- TRIVIAL EQUILIBRIUM :
  $E_0(0,0,0,0)$.
- DISEASE-FREE EQUILIBRIUM :
- $E_1 = \left(\frac{\Lambda_d}{K_d}, \frac{\kappa_d \Lambda_d}{\mu_d K_d}, 0, \frac{\Lambda_h}{K_h}, \frac{\kappa_h \Lambda_h}{\mu_h K_h}, 0\right)$
- DOG-ENDEMIC, HUMAN DISEASE-FREE EQUILIBRIUM
- $E_2 = \left(\frac{\Lambda_d}{K_d}, \frac{\kappa_d \Lambda_d}{\mu_d K_d}, 0, \frac{\Lambda_h}{K_h}, \frac{\kappa_h \Lambda_h}{\mu_h K_h}, 0\right)$

LOCAL STABILITY ANALYSIS

- STABILITY ANALYSIS OF THE TRIVIAL EQUILIBRIUM

$$J(E_0) = diag(-Kd, -\mu d, -\alpha d, -Kh, -\mu h, -\alpha h).$$

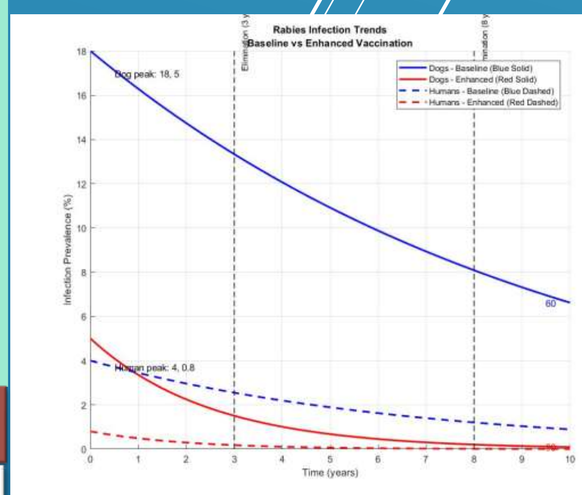
- *Eigen values are real and negative.*
- STABILITY ANALYSIS OF THE DISEASE FREE EQUILIBRIUM

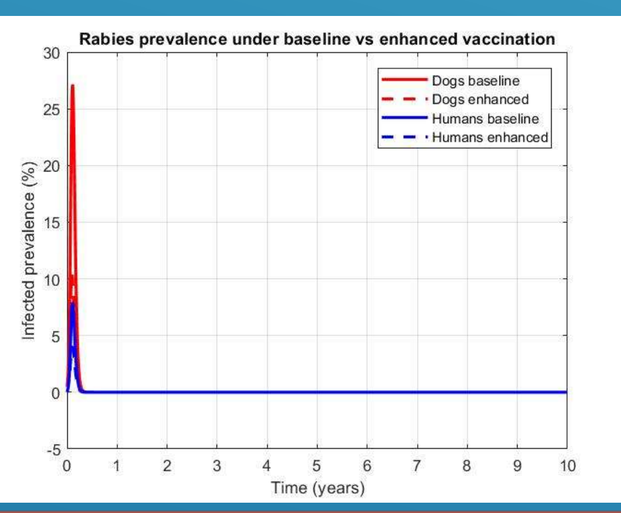
$$R_0 = \frac{\beta_{dd}}{\alpha_d} \cdot \frac{\Lambda_d / K_d}{1 + a_{dd} \Lambda_d / K_d}.$$

- *If $R_0 < 1$, locally asymptotically stable*
- *If $R_0 > 1$, bifurcation arises*
- DOG ENDEMIC AND HUMAN DISEASE FREE EQUILIBRIUM

$$\frac{\beta_{dh} S_h^* I_d^*}{1 + a_{dh} S_d^* + b_{dh} I_d^*} < K_h.$$

NUMERICAL SIMULATIONS





CONCLUSION

Enhanced pharmaceutical parameters significantly increase vaccination impact:

Dog infection reduced from **18% → 5%**

Human infection reduced from **4% → 0.8%**

Elimination time shortened from **8 years → 3 years**

Controlled-release and stability-enhanced vaccines maintain **>90% reduction in transmission for 5 years**, versus **60% for 3 years** with conventional vaccines.