MATHEMATICAL MODELLING OF TRANSMISSION DYNAMICS OF ONCHOCERCIASIS

BAKO, DEBORAH
Department of Mathematics,
Federal University of Technology Minna, Nigeria
Email: deborah.bako@futminna.edu.ng

Abstract
In this paper, a mathematical model for the transmission dynamics and control of Onchocerciasis was developed incorporating the infectious but not blind and the infectious blind compartments. The model consisting of systems of coupled nonlinear ordinary differential equation are used to describe this spread. We obtain the effective reproductive number (R_C)*, and its values computed using five (5) different control strategies were carried out and result shows that although, a 60% treatment coverage rate of infectious but not blind and infectious blind individuals only is better than 80% treatment coverage rate of infectious but not blind individuals only. A 40% coverage rate of fumigation and treatment of infectious but not blind is better than a 40% coverage rate of fumigation only. Further analysis revealed that a 30% coverage rate of fumigation and treatment of infectious blind is better than 80% coverage rate of fumigation only or fumigation and treatment of infectious but not blind only. Also, sensitivity analysis was carried out with respect to the model parameter values to determine the relative importance of each model parameter on the transmission and control of onchocerciasis. From the result, effective fumigation rate* ρ *has the highest sensitivity index followed by the effective contact rate* α_1 *while the negative sensitivity index is* γ_2.

Keywords: Blindness, Differential Transformation, Effective Reproductive number, Equilibrium state, Ivermectin, Onchocerciasis

Introduction
Onchocerciasis (River blindness), infection is one of the neglected tropical diseases targeted for eradication by 2030.Onchocerciasis is a disease that causes visual deficiency (blindness) and it is the second largest cause of blindness after trachoma (Abah *et al.,* 2015). It primarily affects the eyes and the skin. It is transferred from one person to another through the Onchocerca volvulus parasite as a result of a bite from a blackfly that has ingested microfilaria of the class *Simulium damnosum sensulato.* The disease is usually transmitted to humans through the bites of blackflies (Hamley *et al.* 2020). These black flies mostly breed near well-oxygenated fast-running water bodies. The disease is common in mostly remote agricultural villages near rivers and streams. Onchocerciasis starts with Pruritus, which is often the first indication of Onchocerca infection. It may occur on its own or in association with onchocerca skin disease. Troublesome itching, of the body caused by movement of the tiny worms that moves under the skin, change in skin colour, development of white patches on the legs, (leopard skin) (Latipah *et al.* 2020). In the absence of any other pruritic skin condition, patients could be observed using wooden sticks to scratch their skin in an attempt to obtain relief (Abdon *et al.* 2015). Depigmentation (Leopard Skin) this is associated with the skins, calf of the leg, inguinal regions, external genitalia and auxiliary folds in older residents of endemic areas (Bako *et al* 2024). The early age of depigmentation consists of small yellow brown macules resulting in a rather mottled appearance, others include fever and constant headache (Idowu and Ogunmiloro, 2020). Several mathematical models have been used to evaluate intervention strategies concerning onchocerciasis disease. Ogunmiloro and Idowu 2022 adopted the theory of optimal control and explored the effectiveness of controls such as personal protection, treatment with ivermectin and vector control used to combat

onchocerciasis diseases. Their results indicated that vector control was the best among the controls considered.

Also, researchers have conducted various studies exploring potential methods to mitigate the transmission of the disease. Melchers *et al.* 2020, utilized the skin snip survey in West Africa to assess the impact of mitigating black flies through larviciding. In a related study, Adeyemo *et al.* 2024, Asha and Nyimvua 2020, employed computer simulation models to investigate onchocerciasis prevention.

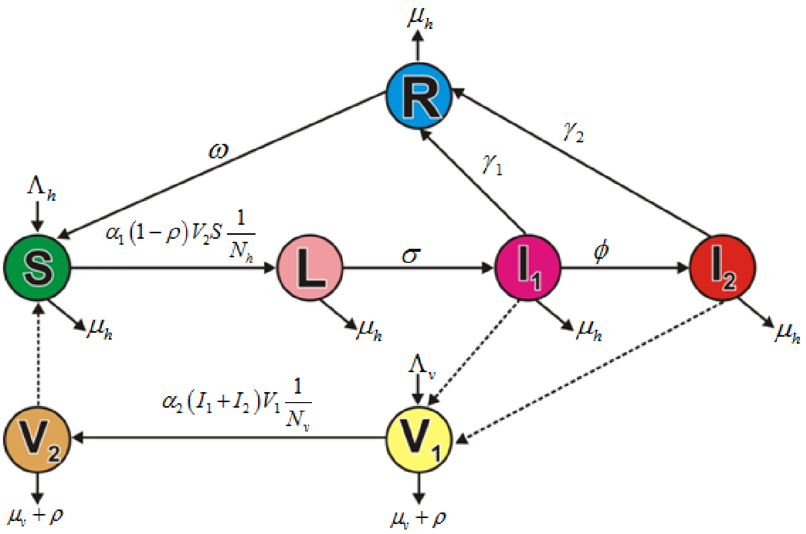
During the last decade, Hamley *et al.,* (2021), Melchers *et al.,* (2020), Latipah *et al.,* (2020), Ogunmiloro and Idowu (2022), Adeyemo *et al.,* (2024), Idowu and Ogunmiloro (2020) and Adeyemo (2023), have designed mathematical models on Onchocerciasis (river blindness). Considering the works of the afore mention authors, the study at hand is an improvement on the cited models above in that it includes;

i. The latent, the infectious blind and recovered classes
ii. The treatment of actively infected individuals and blind as control parameters
iii. Incorporating the fumigation parameter
iv. Loss of immunity after recovered.

Material and Methods

Model Variables and Parameters

The model describes the dynamics of two populations, which is compartmentalized into seven (7) classes interacting with each other namely: the human and vector population.



The model applied has the following variables and parameters:

$S(t)$ Susceptible individuals at time t

$L(t)$ Latently infected individuals at time t

$I_1(t)$ Infectious but not blind individuals at time t

$I_2(t)$ Infectious blind individuals at time t

$R(t)$ Removed individuals due to recovery from infection at time t

$V_1(t)$ Non-carrier vectors at time t

$V_2(t)$	Carriers vectors at time t
Λ_h	Recruitment rate of human through birth
α_1	Effective contact Rate of Onchocerciasis
ρ	Effective Fumigation Rate
σ	Rate of Infection from L to I_1 individuals
γ_1	Treatment rate of I_1 individuals
γ_2	Treatment rate of I_2 individuals
μ_h	Mortality rate due to Onchocerciasis
ω	Waning Rate due of Temporal Immunity of Recovered individuals
μ	Natural death rate of humans
α_2	Progression Rate of infection in the vector
μ_v	Natural death rate of vectors
Λ_v	Recruitment rate of blackfly through birth

Model Development

The Susceptible human population (S) is generated at a constant rate Λ_h via recruitment of humans by birth and immigration into the population. It is further increased by recovered individuals losing immunity at the rate ω. It is decreased by infection acquired via contact with carrier vectors at a rate α_1 where $\rho\left(i.e\ 0<\rho<1\right)$ is the effective fumigation rate. It is further decreased by natural death at the rate μ_h. All the newly infected susceptible individuals moved to the latently infected compartment(L). The Latent compartment (L) is decreased by progression of the disease to infectious but not blind class I_1 and natural death at the rates σ and μ_h respectively. It is further decrease due to following interaction with the non-carrier vector (V_1). The infectious but not blind (I_1) population is increased by progression of latently infected individuals at the rate σ and decreases by complications of the infection resulting into blindness at the rate ϕ, it further decreases by recovery due to treatment to the recovered class at the rate γ_1 and natural death also occurs at the rate μ_h. The infectious blind compartment (I_2) is increased at the rate ϕ due to progression of infection from I_1 class and diminished by recovery due to treatment from *Onchocerca volvulus* (not the blindness) and natural death at the rate γ_2 and μ_h respectively. The recovered compartment (R) is generated from recovered individuals from the I_1 and l_2 classes at the rates γ_1 and γ_2 respectively. It diminishes by losing immunity and natural death at the rates ω and μ_h respectively. The non-carrier vectors, $(V_1)$are generated via birth or immigration of vectors into the population at the rate Λ_v. It decreases by infection acquired when the non-carrier vectors feed from the blood of the I_1 or the I_2 individuals at the rate α_2. The vectors sub-population diminishes by natural death or larvicides at the rates μ_v and ρ respectively. The Carrier vectors (V_2) are generated from the Non-carrier vectors (V_1) that feed on infectious blood meals and similarly diminishes at the rates μ_v and ρ respectively.

Mathematical representation of the Schematic diagram is given by the following ordinary differential equations.

The corresponding mathematical model equations are described by a system of Ordinary Differential Equations (ODEs) given below:

$$\left.\begin{aligned}
\frac{dS}{dt} &= \Lambda_h - \frac{\alpha_1(1-\rho)V_2S}{N_h} + \omega R - \mu_h S \\
\frac{dL}{dt} &= \Lambda_h - \frac{\alpha_1(1-\rho)V_2S}{N_h} - (\sigma + \mu_h)L \\
\frac{dI_1}{dt} &= \sigma L - (\phi + \gamma_1 + \mu_h)I_1 \\
\frac{dI_2}{dt} &= \phi I_1 - (\gamma_2 + \mu_h)I_2 \\
\frac{dR}{dt} &= \gamma_1 I_1 + \gamma_2 I_2 - (\omega + \mu_h)R \\
\frac{dV_1}{dt} &= \Lambda_v - \frac{\alpha_2(I_1+I_2)V_1}{N_v} - (\mu_h + \rho)V_1 \\
\frac{dV_2}{dt} &= \frac{\alpha_2(I_1+I_2)V_1}{N_v} - (\mu_h + \rho)V_2
\end{aligned}\right\}$$

(1)

where

$$N_h(t) = S(t) + L(t) + I_1(t) + I_2(t) + R(t) \quad (2)$$

$$N_v(t) = V_1(t) + V_2(t) \quad (3)$$

So that

$$\frac{dN_h(t)}{dt} = \Lambda_h - \mu_h N_h(t) \quad (4)$$

$$\frac{dN_v(t)}{dt} = \Lambda_v - (\mu_v + \rho)N_v(t) \quad (5)$$

in the biological feasible region:

$$\Omega = \left\{ \begin{pmatrix} S \\ L \\ I_1 \\ I_2 \\ R \\ V_1 \\ V_2 \end{pmatrix} \in \mathbb{R}_+^7 \;\middle|\; \begin{array}{c} S \geq 0, \\ L \geq 0, \\ I_1 \geq 0, \\ I_2 \geq 0, \\ R \geq 0, \\ V_1 \geq 0, \\ V_2 \geq 0, \\ \\ S + L + I_1 + I_2 + R + V_1 + V_2 \end{array} \right\} \quad (6)$$

Setting

$$\left.\begin{aligned} &\theta = 1-\rho \\ &k_1 = \sigma + \mu_h \\ &k_2 = \phi + \gamma_1 + \mu_h \\ &k_3 = \gamma_2 + \mu_h \\ &k_4 = \omega + \mu_h \\ &k_5 = \mu_v + \rho \end{aligned}\right\} \qquad (7)$$

System (1) becomes

$$\left.\begin{aligned} \frac{dS}{dt} &= \Lambda_h - \frac{\alpha_1 \theta V_2 S}{N_h} + \omega R - \mu_h S \\ \frac{dL}{dt} &= \frac{\alpha_1 \theta V_2 S}{N_h} - k_1 L \\ \frac{dI_1}{dt} &= \sigma L - k_2 I_1 \\ \frac{dI_2}{dt} &= \phi I_1 - k_3 I_2 \\ \frac{dR}{dt} &= \gamma_1 I_1 + \gamma_2 I_2 - k_4 R \\ \frac{dV_1}{dt} &= \Lambda_v - \frac{\alpha_2 (I_1 + I_2) V_1}{N_v} - k_5 V_1 \\ \frac{dV_2}{dt} &= \frac{\alpha_2 (I_1 + I_2) V_1}{N_v} - k_5 V_2 \end{aligned}\right\} \qquad (8)$$

It can be seen that all solutions of the system starting in Ω remains in Ω for all $t \geq 0$, thus is positively invariant and sufficient to the solutions in Ω.

Existence of Onchocerciasis-free Equilibrium State $\left(E^0\right)$

At the disease-free equilibrium state there is absence of infection, there is no infection

$$\begin{pmatrix} S \\ L \\ I_1 \\ I_2 \\ R \\ V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} S^0 \\ L^0 \\ I_1^0 \\ I_2^0 \\ R^0 \\ V_1^0 \\ V_2^0 \end{pmatrix} \qquad (9)$$

Now, substituting and solving simultaneously yields

$$V_1^0 = \frac{\Lambda_v}{k_5} \qquad (10)$$

$$S^0 = \frac{\Lambda_h}{\mu_h} \tag{11}$$

Thus a onchocerciasis-free equilibrium state of the model exists at the point

$$\begin{pmatrix} S \\ L \\ I_1 \\ I_2 \\ R \\ V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} \frac{\Lambda_h}{\mu_h} \\ 0 \\ 0 \\ 0 \\ 0 \\ \frac{\Lambda_v}{k_5} \\ 0 \end{pmatrix} \tag{12}$$

Effective Reproductive number (R_C)

One of the most important concern in the analysis of epidemiological models is the determination of the asymptotic behaviour of their solution which is usually based on the stability of the associated equilibria. These models typically consist of disease-free equilibrium and at least one endemic equilibrium. The local stability is determined based on a threshold parameter known as basic reproduction number R_0 this represents the average number of secondary cases generated by an infected individuals if introduced into a susceptible population with no immunity to the disease in the absence of interventions to control the infection. If $R_0 < 1$, then on average, an infected individual produces less than one newly infected individual over the course of its infection period. In this case, the infection may die out in the long run. Conversely, if $R_0 > 1$, each infected individual produces, on average more than one new infection, the infection will be able to spread in a population. A large value of (R_0) may indicate the possibility of a major epidemic. Similarly, the effective reproductive number (R_C) represents the average number of secondary cases generated by an infected individual if introduced into a susceptible population where control strategies are used (Bako *et al.,* 2024).

A better widely accepted and used method for finding (R_0) that reflect its biological meaning is the next generation operator approach described by Diekmann and Heesterbeek (2000) and subsequently analysed by Van de Driessche and Watmough (2002), Heesterbeek (1996). Using this technique we obtained the effective reproductive number, (R_C) of the system (1) which is the spectral radius (ρ) of the next generation matrix, (K), that is (R_C) $R_C = \rho(FV^{-1})$. Both *F* and *V* are obtained from the Jacobian matrix of the linearization of the system (1) about the disease-free equilibrium. *F* is the matrix of the new infection terms and *V* the matrix of the transition terms. Noting that, the matrices *F* and *V* are formed from the coefficients of the infected classes, i.e. (L, I_1, I_2, V_2), in the system(1).

Then,

$$F = \begin{pmatrix} 0 & 0 & 0 & \alpha_1\theta \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & \alpha_2 & \alpha_2 & 0 \end{pmatrix} \tag{13}$$

and

$$V = \begin{pmatrix} k_1 & 0 & 0 & 0 \\ -\sigma & k_2 & 0 & 0 \\ 0 & -\phi & k_3 & 0 \\ 0 & 0 & 0 & k_5 \end{pmatrix} \tag{14}$$

$$R_c = \sqrt{\frac{\alpha_1\alpha_2\theta\sigma(k_3+\phi)}{k_1k_2k_3k_5}} \tag{15}$$

Solution via Differential Transformation Methods (DTM)

Differential Transform Methods is used to solve the model equation of the system (1) passing through the initial value conditions of the variables.

Let

$$S = y_1, L = y_2, I_1 = y_3, I_2 = y_4, R = y_5, V_1 = y_6, V_2 = y_7 \tag{16}$$

Substituting this into system (1) with initial condition

With initial conditions;

$$y_1(0) = 175{,}914{,}033, y_2(0) = 2{,}500{,}000, y_3(0) = 1{,}997{,}827,$$
$$y_4(0) = 300{,}000, y_5(0) = 850{,}196, y_6(0) = 2{,}776{,}642{,}857, y_7 = 500{,}000 \tag{17}$$

Where

$\Lambda_h, \alpha_{1,}\alpha_{2,}\rho, N_h, \omega, \mu_{h,}\sigma, \phi, \gamma_{1,}\gamma_{2,}\Lambda_{v,}\mu_{h,}N_v$ are real.

Substituting the values of parameters into our model equations we have;

yields

$$\frac{dy_1}{dt} = 3449679 - 0.000000002335y_7y_1 + 0.019y_5 - 0.019y_1 \tag{18}$$

$$\frac{dy_2}{dt} = \Lambda_h - \frac{\alpha_1(1-\rho)y_7y_1}{N_h} + (\delta + \mu_h)y_2$$

$$\frac{dy_2}{dt} = 0.000000002335y_7y_1 - 0.519y_2 \tag{19}$$

$$\frac{dy_3}{dt} = \delta y_2 - (\phi + \gamma_1 + \mu_h)y_3$$

$$\frac{dy_3}{dt} = 0.5\,\mathrm{y}_2 - 1.586y_3 \tag{20}$$

$$\frac{dy_4}{dt} = \phi y_3 - (\gamma_2 + \mu_h)y_4$$

$$\frac{dy_4}{dt} = 1.5\,\mathrm{y}_3 - 0.086y_4 \tag{21}$$

$$\frac{dy_5}{dt} = y_1y_3 + y_2y_4 - (\omega + \mu_h)y_5$$

$$\frac{dy_5}{dt} = 0.067\,\mathrm{y}_3 + 0.067y_4 - 0.038y_5 \qquad (22)$$

$$\frac{dy_6}{dt} = \Lambda_v - \frac{\alpha_2 y_3 y_6}{N_v} + \frac{\alpha_2 y_4 y_6}{N_v} - (\mu_v + \rho)y_6$$

$$\frac{dy_6}{dt} = 361,029 - 0.0000000000144y_3y_6 - 0.0000000000144y_4y_6 - 0.80013y_6 \qquad (23)$$

$$\frac{dy_7}{dt} = \frac{\alpha_2 y_3 y_6}{N_v} + \frac{\alpha_2 y_4 y_6}{N_v} - (\mu_v + \rho)y_7$$

$$\frac{dy_7}{dt} = 0.0000000000144y_3y_6 + 0.0000000000144y_4y_6 - 0.80013y_6 \qquad (24)$$

We take the differential transform of the above equations and obtained;

$$(k+1)Y_1(k+1) = 34496798\delta(k) - 0.000000002335\sum_{r=0}^{k} Y_1(r)Y_7(k-r) + 0.019Y_5(k) - 0.019Y_1(k) \qquad (25)$$

$$(k+1)Y_2(k+1) = 0.000000002335\sum_{r=0}^{k} Y_1(r)Y_7(k-r) - 0.519Y_2(k) \qquad (26)$$

$$(k+1)Y_3(k+1) = 0.5Y_2(k) - 1.586Y_3(k) \qquad (27)$$

$$(k+1)Y_4(k+1) = 1.5Y_3(k) - 0.086Y_4(k) \qquad (28)$$

$$(k+1)Y_5(k+1) = 0.067Y_3(k) - 0.067Y_4(k) - 0.038Y_5(k) \qquad (29)$$

$$\left.\begin{aligned}(k+1)Y_6(k+1) = 3610298(k) - 0.0000000000144\sum_{r=0}^{k} Y_3(r)Y_7(k-r) - \\ 0.0000000000144\sum_{r=0}^{k} Y_3(r)Y_7(k-r) - 0.80013Y_6(k)\end{aligned}\right\} \qquad (30)$$

$$\left.\begin{aligned}(k+1)Y_7(k+1) = 0.0000000000144\sum_{r=0}^{k} Y_3(r)Y_6(k-r) + \\ 0.0000000000144\sum_{r=0}^{k} Y_4(r)Y_6(k-r) - 0.80013Y_7(k)\end{aligned}\right\} \qquad (31)$$

For $k = 0,1,2,3,...$ (32)

When $k = 0,$ we have the first iteration as follows;

$Y_1(1) = -819,913.5365$ (33)

$Y_2(1) = -1,092,120.366$ (34)

$Y_3(1) = -1,918,553.622$ (35)

$Y_4 = 2,970,940.5$ (36)

$Y_5(1) = 81,446.961$

$Y_6(1) = -2,221,767.125$ (37)

$Y_7(1) = -308,189.4731$ (38)

When $k = 1,$ we have the second iteration as follows;

$Y_1(2) = 72,337.3903$

$$Y_2(2) = -127,548.9298 \quad (39)$$

$$Y_3(2) = 1,794,443.114$$

$$Y_4(2) = 1,566,665.658 \quad (40)$$

$$Y_5(2) = -165,345.5453 \quad (41)$$

$$Y_6(2) = 102,293.4412$$

$$Y_7(2) = 84,908.4678 \quad (42)$$

When $k = 2$, we have the third iteration as follows;

$$Y_1(3) = -11,261.4224 \quad (43)$$

$$Y_2(3) = 24,252.6539 \quad (44)$$

$$Y_3(3) = -938,033.1821 \quad (45)$$

$$Y_4(3) = 942,132.6392 \quad (46)$$

$$Y_5(3) = 77,159.1395 \quad (47)$$

$$Y_6(3) = -30,308.3807 \quad (48)$$

$$Y_7(3) = -19,620.2404 \quad (49)$$

and so on;
A closed form of this solution can be written as follows;

$$y(t) = \sum_{k=o}^{\infty} Y(k)t^k \quad (50)$$

The solution for $y_1(t)$ is given below;

$$y_1(t) = Y_1(0) + tY_1(1) + t^2Y_1(2) + t^3Y_1(3) + \ldots \quad (51)$$

$$y_1(\mathrm{t})175,914,033 - 819,913.5365t + 72,337.3903t^2 - 11,261.4224t^3 + \ldots \quad (52)$$

The solution for $y_2(t)$ is given below;

$$y_2(t) = Y_2(0) + tY_2(1) + t^2Y_2(2) + t^3Y_2(3) + \ldots$$

$$y_2(t) = 250,000 - 1,092,120.366t + 63,774.4649t^2 + 24,252.6539t^3 + \ldots \quad (53)$$

The solution for $y_3(t)$ is given below;

$$y_3(t) = Y_3(0) + tY_3(1) + t^2Y_3(2) + t^3Y_3(3) + \ldots \quad (54)$$

$$y_3(t) = 1,997,827 - 1,918,553.622t + 1,794,443.114t^2 - 938,033.1821t^3 + \ldots \quad (55)$$

The solution for $y_4(t)$ is given as follow

$$y_4(t) = 300,000 + 2,970,940.5t + 1,566,665.658t^2 + 942,132.6392t^3 + \ldots \quad (56)$$

The solution for $y_5(t)$ is given below;

$$y_5(t) = Y_5(0) + tY_5(1) + t^2Y_5(2) + t^3Y_5(3) + \ldots \quad (57)$$

$$y_5(t) = 850,196 + 81,446.961t + 165,345.5453t^2 + 77,159.1395t^3 + \ldots \quad (58)$$

The solution for $y_6(t)$ is given below;

$$y_6(t) = Y_6(0) + tY_6(1) + t^2Y_6(2) + t^3Y_6(3) + \ldots \quad (59)$$

$$y_6(t) = 2,776,642,857 - 2,221,767.125t + 102,293.4412t^2 - 30,308.3807t^3 + \ldots \quad (60)$$

The solution for $y_7(t)$ is given below;

$$y_7(t) = Y_7(0) + tY_7(1) + t^2Y_7(2) + t^3Y_7(3) + \ldots \quad (61)$$

$$y_7(0) = 500,000 - 308,189.4731t + 84,908.4678t^2 - 19,620.2404t^3 + \ldots \quad (62)$$

Results and Discussion

In this section, we presented some numerical simulation to monitor the dynamics of the full model (1) for various values of effective reproductive number in order to confirm our analytical results on the global stability of the Onchocerciasis-free equilibrium as well as effect of different control strategies.

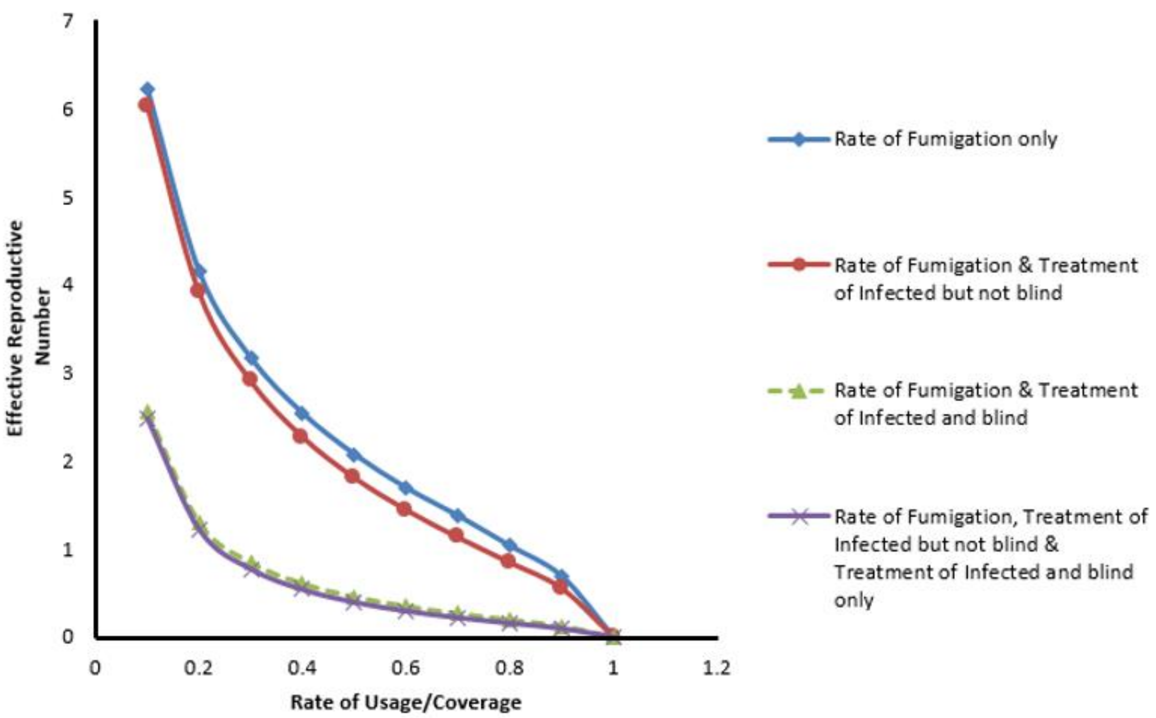


Figure 2: Comparison between the four control strategies and the Effective Reproduction Number at Different Coverage Rate

Figure 2 reveals that the four control strategies reduce the effective reproductive number below unity. Although, a 40% coverage rate of fumigation and treatment of Infectious but not blind is better than a 40% coverage rate of fumigation only. It further reveals that a 30% coverage rate of fumigation and treatment of Infectious but not blind is better than 80% coverage rate of fumigation only or fumigation and treatment of Infectious but not blind only.

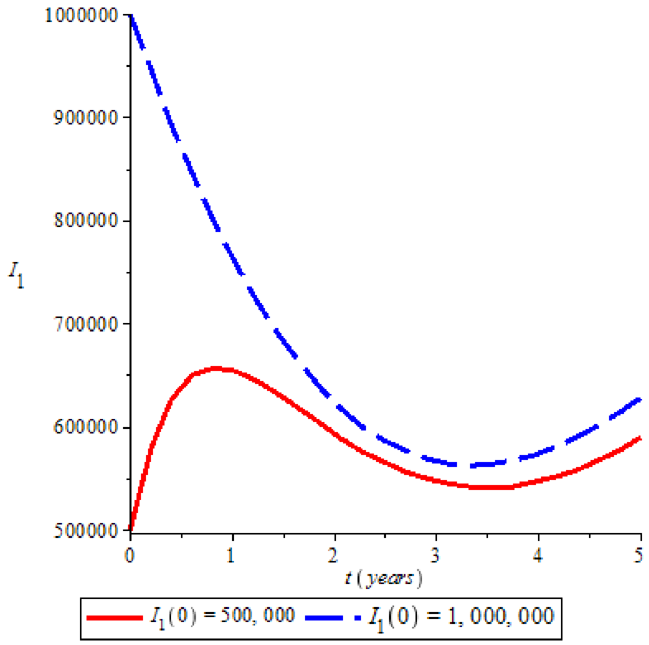


Figure 3: Total number of infectious but not blind with different initial variable conditions

In Figure 3, the $I_1 = 50000$ and $I_1 = 1,000,000$. Control Parameters used are $I_1 = 500,000$, and $I_1 = 1,000,000$ which gives $R_C = 14.96388$ when $\gamma_1 = 0.0001$ $\gamma_2 = 0.0001,$ $\rho = 0.0001$. It is clear from the above that the solutions profiles of equation 1 converges to the endemic equilibrium in each of these two different initial values of $I_1(0)$. This shows the local and the global asymptotic stability of the endemic equilibrium.

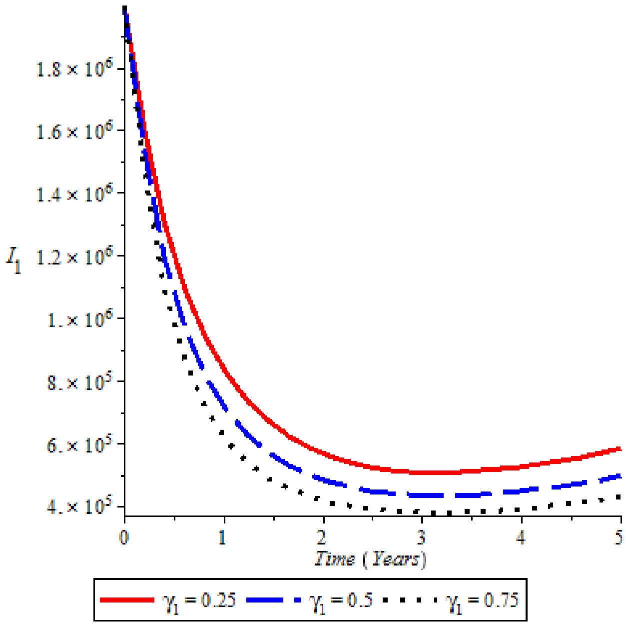


Figure 4: A comparison between the effects of treatment of Infectious but not blind on the morbidity of I_1 individuals.

In Figure 4, the Initial parameters and values used are $\gamma_1 = 0.25, \gamma_1 = 0.5$ and $\gamma_1 = 0.75$. This shows that more of the Infectious individuals should be treated with Ivermectin annually, since 75% treatment rate of Infectious but not blind reduces the morbidity to a disease-free equilibrium in the first three (3) years. Hence, it is advice that 75% treatment will reduce onchocerciasis to a disease-free equilibrium state.

Conclusion

Here we present a model mathematically for curbing of Onchocerciasis by integrating the infectious but not blind and the infectious blind classes. It is proved that the model is mathematically well posed and epidemiologically meaningful in this feasible region. The effective reproductive number R_c, which is a threshold for disease control is obtained. A sensitivity analysis of the R_c using the model parameters was carried out and found that the highest sensitivity parameters of the Onchocerciasis model are identified, effective fumigation rate ρ denotes the most sensitivity index next followed by the effective contact rate α_1 and the smallest sensitive is μ_v.

Also, the Differential Transformation Method (DTM) has been successfully applied to approximately solve a system of nonlinear equations on Onchocerciasis dynamics and control. The result shows the potential efficiency of DTM in solving nonlinear problems. It can thus be concluded that when combined with high performance computer and symbolic computation software such as Maple, Mathlab, Mathematica and so on, the Differential Transformation Method stand a chance of becoming a new powerful analytic tool to obtain satisfactory non-linearized and unperturbed approximations for nonlinear problems unrestrictive assumptions in science and engineering.

References

Abah, R. T., Akinwande N. I., Enagi A. I., Kuta, I. A., Abdulrahman, S., & Somma, S. (2015). Stability analysis of the disease-free equilibrium state of a mathematical model of ebola fever disease epidemic. *International Journal of Innovation in Science and Mathematics,* 3(2), 118-123.

Abdon, A., & Rubayyi, T. A. (2015). Modelling the spread of river blindness disease via the caputo-fractional derivative and beta–derivative.

Adeyemo, K. M., (2023). Local stability analysis of onchocerciasis transmission dynamics with nonlinear incident function in two interacting populations. *Journal of Mathematics Anal,* 3,22.

Adeyemo, K. M., Adam, U. M., Adeniji, A., & Oshinubi, K. (2024). Mathematical modelling of two interacting population dynamics of onchocerciasis disease spread with nonlinear incidence functions. *Journals of mathematics*, 12(2), 222.

Asha, H., & Nyimvua, S. (2020). Modelling the effects of treatment, education and vector control. *Journal of Biological Dynamics*, 14(1).

Bako, D., & Yusuf, I. (2024). Mathematical modelling on the impact of educational factors on the control of marital conflict (JOBASR). *Journal of Basics and Applied Sciences Research (JOBASR),* 2(3). https://doi.org/10.33003/jobasr-2024-v2i3-

Bako, D**.,** Odo, C. E., Oluwafemi, T. J., Oladejo, J. K. (2024). Semi-analytic solution of mathematical model of disease dynamics in school using homotopy perturbation method (HPM). *FUDMA Journal of Sciences (FJS)*, 8(6), 2645–2944. https://doi.org/10.33003/f js-2024-0806-2703

Castillo-Chavez, C., Feng, Z., & Huang, W. (2002). On the computation of R_0 and its role on global stability. In C. Castillo-Chavez, S. Blower, P. Van den Driessche, D. Krirschner & A. A. Yakubu (Eds), *Mathematical approaches for emerging and re-emerging infectious diseases: Vol. 125, An introduction. The IMA Volumes in Mathematics and its Applications* (pp. 229-250). New York: Springer-Verlag.

Diekmann, O., & Heesterbeek, J. A. P. (2000). *Mathematical epidemiology of infectious diseases: Model building, analysis and integration*. New York: Wiley.

Hamley J. I., Walker M., Coffeng, L. E., Milton, P., de Vlas, S. J; Stolk, W. A., & Basanez, M. G. (2020). Structural uncertainty in onchocerciasis transmission models influences the estimation of elimination thresholds and selection of age groups for seromonitoring. *Journal infectious Disease*, 221, S510-S518.

Hamley, J. I., Blok, D. J., Walker, M., Milton, P., Hopkins, A. D., Hamill, L. C., Downs, P., De Vias, S. J., Stolk, W. A., & Basanez, M. G. (2021). What does the Covid -19 pendemic mean for the next decade of Onchocerciasis control and elimination? *Trans.R. Soc. Trop. Med. Hyg.* 2021, 115, 269-280 [Google scholar]

Heesterbeek, J. A. P., & Dietz, K. (1996). The concept of R_0 in epidemic theory. *Statistica Neerlandica, 50*, 89-110.

Idowu, W. S., & Ogunmiloro, O. M. (2020). Transmission dynamics of Onchocerciasis with two classes of infection and saturated treatment function. *Int. Journal model Simul. Sci. Comput 2020,* 11, 2050047.

Latipah, K., Putri, A., & Syafwan, M. (2020) Stability analysis of prey predator model holling type II with infected prey. *Journal phy Conf. SC 2020,* 1554, 012038

Melchers, N. V., Coffeng, L. E., Boussinesq, M., Pedrique, B., Pion, S. D., Tekle, A. H., Zoure, H. G., Wanji, S., Remme, J. H., & Stolk, W. A. (2020). Projected number of people with Onchocerciasis Loiasis coinfection in Africa, 1995 to 2025. *Journal of clinical Infect. Dis 2020 70 2281-2289,* Oxford University Press.

Ogunmiloro, O. M., & Idowu A. S. (2022) Bifurcation, sensitivity and optimal control analysis of onchocerciasis disease transmission model with two group of infectives and saturated treatment function. *Math. Methods Appl. Sci*, 2022, 6, 12-29.