Lab - 6

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CS-302, Modeling and Simulation

In this lab we have modeled spreading of the malaria disease.We have discussed how this disease spreading with the time in the human population through vector mosquito.In order stop the spreading some we have incorporated some of the human interventions like in the model to it model more realistic.Finally we have suggested some step to avoid the spared of disease like this using our numerical analysis and observation of our model.

I. INTRODUCTION

Malaria is one the most life threatening disease in the world.In the year 2019, there were an estimated 229 million cases of malaria worldwide there for it's important to study of this disease by building the mathematical model to have better control.

This disease is spread by female anopheles mosquito or vector mosquito which contains plasmodium parasite.when mosquito bits the susceptible human then the plasmodium parasite transmitted form the mosquito into the human.When uninfected mosquito bites the host human then the mosquito become infected and become vector mosquito so because of this bidirectional dependency of this disease it's quit difficult to understand the spread,when infected human travels to different region then the spreading might started there.

II. BASIC MALARIA MODEL

In this model we divided the whole human population into 3 parts (1)Uninfected humans (2)Infected human/host (3)Immune human, while the population of misquotes divided into 2 parts (1)Uninfected (2)infected/vectors.The model works like this, If an uninfected mosquitoes bits the host person then its immediately becomes vector and when vector mosquito bites the uninfected human then he/she becomes host immediately. There are 3 possible outcomes of the host (1)Host becomes uninfected (2)Death of host (3)Host becomes immune.we have made some assumption while building a model to made our task easy.

A. Assumptions

1. Once person gets immune then he/she never become host in future.
2. No natural birth and deaths of human throughout the time period although deaths due to disease are incorporated in the model.
3. Since lifetime of mosquitoes are smaller, we incorporated natural deaths and births.
4. population is homogeneously mixed and have the same immune system and other biological properties through out the time period.
5. We assumed that initially there is on host human/animal from which disease might spread.

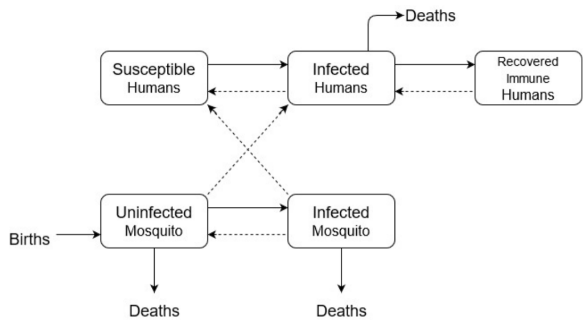

FIG. 1: Basic Malaria Model

B. Mathematical equations of model

- flow_to_immune = immunity_rate * human_hosts
- human_host_deaths = malaria_induced_death_rate * human_hosts
- recovered_people = recovery_rate * human_hosts
- mosquito_births = mosquito_birth_rate * mosquitoes ,where mosquitoes = uninfected_mosquitoes + vectors
- uninfected_mosquito_deaths=mosquito_death_rate * uninfected_mosquitoes
- vector_deaths = mosquito_death_rate * vectors

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- d(uninfected_humans)/dt=(recovery_rate)* (human_hosts) - (bite_probability) * (vector) * (uninfected _humans)/mosquitoes ,where bite_probability is a probability of a mosquito biting the human.

- d(vector_formation)/dt=(bite_probability) * (probability_of_host_human) * (uninfected_mosquitoes)

C. Concept of basic reproduction number($\mathbf{R}_0$)

Now We will see one numeric constant called basic reproduction number(R_0) which is nothing but gives the expected number of the people infected by 1 person or in other word the total new infection happened during the recovery time of one host.

Lets define the basic reproduction number in a simpler term.

$$R_0 = \frac{infection\_rate}{Malaria\_induced\_death\_rate + recovery\_rate}$$

Now infection rate is it self consist of many factors like population of vector mosquitoes,bite rate,In addition to that the population of vector mosquitoes is also depends on bites rate and population of human host.

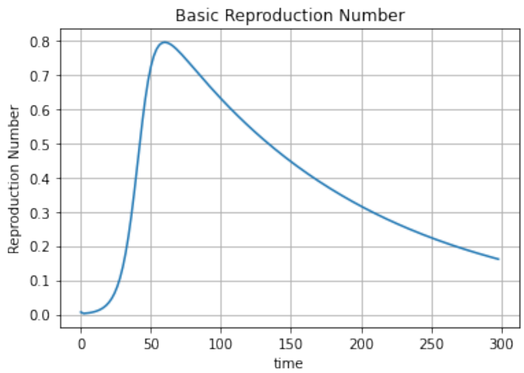

FIG. 2: reproduction number(R_0) over time T

Initially , there are more number of susceptible so, more number of humans can infect so, value of R_0 increasing. after infected humans reaches to its maximum R_0 also, reaches to its maximum. after this number of susceptible decreases so, that infected people also decreases.resulting to that R_0 decreases.In this type of system the rate of infection depended up on vector mosquitoes while rate of infection in mosquitoes dependent up on the host human population because of that both the population decide the outcome of the system.typically this system goes into positive loop in which both the human host and mosquitoes increases and after reaching some maximum value the system goes into negative loop and we see decrees in the both commodity.

D. Analysis of basic malaria model

We saw the theoretical description of the malaria model now we have implemented the model by taking the below parameters and it's value for the entire discussion.

- Initial uninfected humans = 300
- Initial host population = 1
- Initial immune population = 0
- Initial uninfected mosquitoes = 300
- Initial infected mosquitoes = 0
- Recovery_rate = 0.3
- Immunity_rate = 0.01
- Malaria_induced_death_rate = 0.005
- Mosquito_birth_rate = 0.01
- Mosquito_death_rate = 0.01
- Bite_probability = 0.3

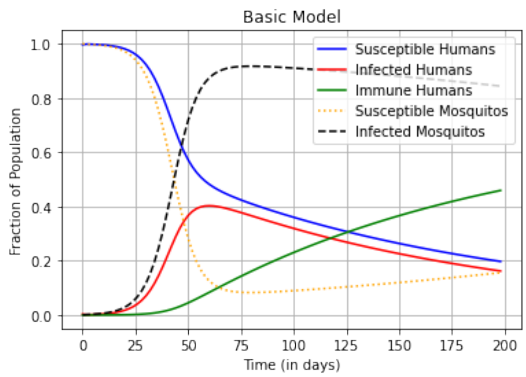

FIG. 3: fraction of humans and mosquitoes of each categories for 200 days

As, we can observer from the figure(3) that infected people and infected mosquitoes are increased exponentially. so, as a result of that susceptible people and susceptible mosquitoes decreases.After some time as the immune people increases, less number of mosquitoes infected from human host so, as a result of that number of infected human decreases.

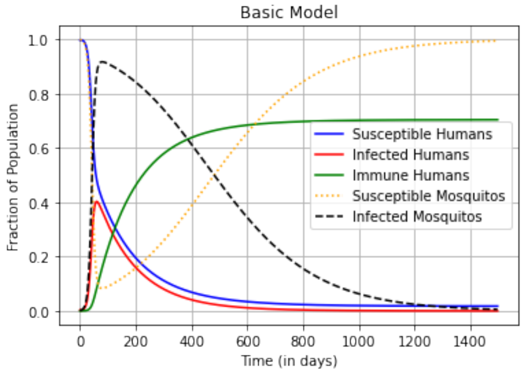

FIG. 4: fraction of humans and mosquitoes of each categories for 1500 days

we can see from the figure(4) that initially in sharp rise in infected humans and infected mosquitoes and reaches to peak value.After this infected humans keep decreasing and hence infected mosquitoes are also decreasing and eventually both become zero since we didn't take birth of the humans into account.As time elapse every human will either immunize or die so, no new infection arise.

III. MODEL WITH THE EFFECT OF VACCINATION

One way to prevent spread of malaria is vaccination.we have made some assumption while building a model with vaccination.

A. Assumptions

1. only susceptible humans will get vaccinated.
2. after vaccination person will become immune immediately.
3. each day some constant fraction of people will get vaccine.

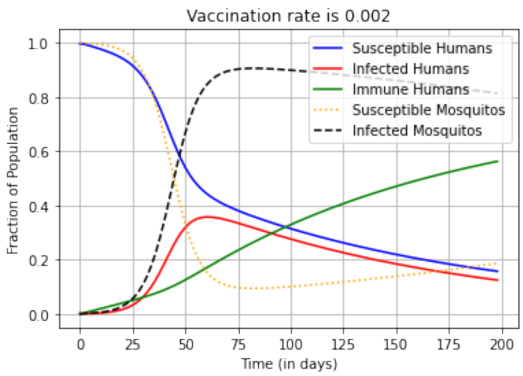

FIG. 5: fraction of humans and mosquitoes of each categories for 200 days with vaccination rate 0.002

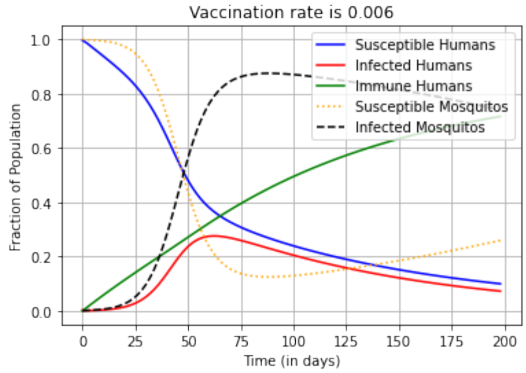

FIG. 6: fraction of humans and mosquitoes of each categories for 200 days with vaccination rate 0.006

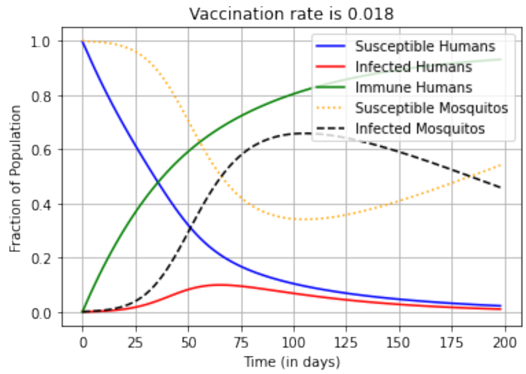

FIG. 7: fraction of humans and mosquitoes of each categories for 200 days with vaccination rate 0.018

as we can from the above figures(5),(6) and (7) that as we increase vaccination rate then maximum infected people and infected mosquitoes both decreases because they are actually depends on the others population. also, as we increase vaccination rate saturation of there is increase in the immune humans after spread of disease ended.The possible reason behind this is that as we increase vaccination rate, more and more people becomes immune due to vaccine and because of that , there are less susceptible to become infected and also, less people will die.s

IV. MODEL WITH THE EFFECT OF FUMIGATION

In the technique of fumigation number of infected and uninfected mosquitoes will decrease and due to that spread of disease decreases.we have made some assumption while building a model with fumigation.

A. Assumptions

1. fumigation are taken every day.

2. due to fumigation susceptible and infected both type of mosquitoes die.

3. mosquitoes are die with constant rate due to fumigation.

4. fumigation are done every places where this disease was spread.

5. fumigation only affect to mosquitoes.

6. fumigation rate means fraction of mosquitoes that will die due to fumigation.

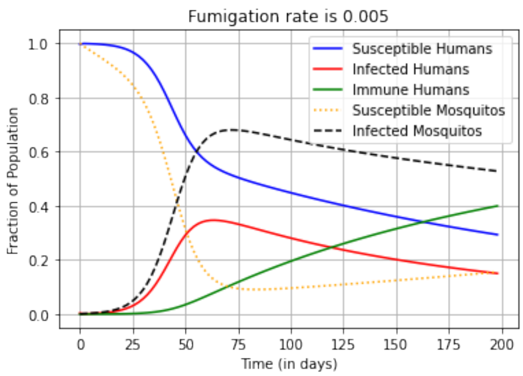

FIG. 8: fraction of humans and mosquitoes of each categories for 200 days with fumigation rate 0.005

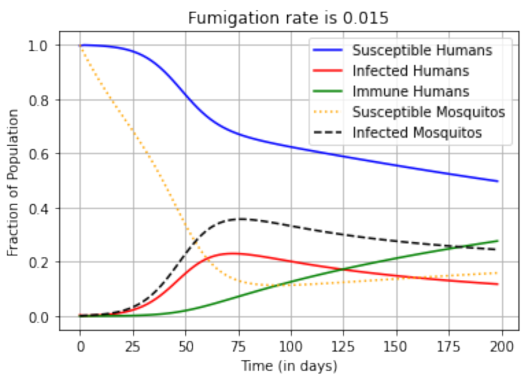

FIG. 9: fraction of humans and mosquitoes of each categories for 200 days with fumigation rate 0.015

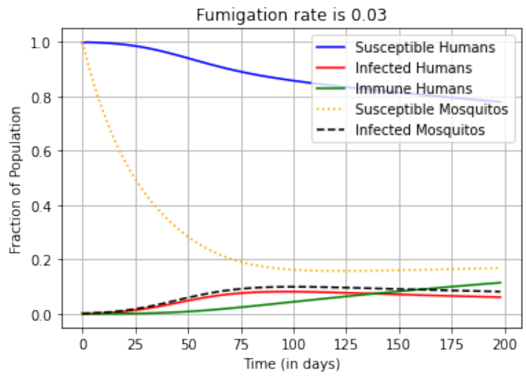

FIG. 10: fraction of humans and mosquitoes of each categories for 200 days with fumigation rate 0.03

as we can from the above figures(8),(9) and (10) that as fumigation rate increases peak of infected humans and peak of infected mosquitoes both are decreases because as more fumigation rate leads to die out more number of mosquitoes.also, time to saturate susceptible humans become zero is decreases because of the slow infection spread.

V. MODEL WITH THE EFFECT OF FUMIGATION AND VACCINATION BOTH

As we discussed above model that both models with fumigation and vaccination are significantly effective.but if we want to decrease further we can use both the models simultaneously.

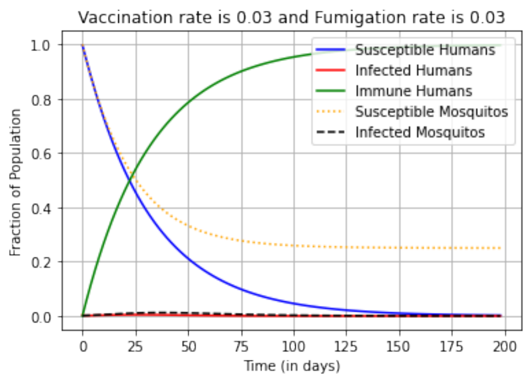

FIG. 11: fraction of humans and mosquitoes of each categories for 200 days with fumigation rate 0.03 and vaccination rate 0.03

we can see from the above figure(11) that peak of the infected humans is further decreases and also, people are immunize very fast.also, time for susceptible humans to become zero very low.So,for optimize the spread of disease we can use both simultaneously.

VI. DENGUE OUTBREAK AT DA-IICT

- In the context of our collage, This is perfect environment for the mosquitoes to grow their population so despite of fumigation, after some days the population rise up to the previous level.
- In this situation we have less control over the population of mosquitoes but the population of human host are in our hand.The meaning of this students need to be careful and obey the proper hygiene and before going out side of the room student need to protect them self by applying mosquito repellent(ie,Odomous gel,band or the spray).May be institute provide this
- In addition to that as soon as the institute gets the first dengue case they should immediately fumigate and doing this for 2 to 3 days consecutively instead of doing weekly,to achieve minimal vector mosquito population.

VII. CONCLUSION

- We analyse the effect of fumigation, effect of vaccination separately and then we analyse the effect of both simultaneously.
- we can conclude that vaccination helps to immunize people so, the susceptible people decrease and the intensity of spread is decreases.
- we can also conclude that fumigation can helps to reduce the infected mosquitoes as a result of that spread also decreases.
- So, for the most effective way to control the spread of diseases is doing both the vaccination and fumigation regularly.

[1] A. Shiflet and G. Shiflet, *Introduction to Computational Science: Modeling an Simulation for the Sciences*, Princeton University Press.3, 276 (2006).