

Assignment 5

Degree Program: Medical Engineering & EHealth

Course: Bioinformatics

Modelling of infectious diseases

Tuberculosis (TB) in Austria (1 year period)

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In 2019 Austria recorded in total 474 infections of tuberculosis. The purpose of the following model is to show the course of TB when no medical interventions are taking place and the infected people are not isolated from society.

TB with no medical intervention and restrictions

Comparing different infection rate values, it can be stated that a person who got infected with TB and does not get any medical intervention, like antituberculosis, can be contagious for up to 30 days. In some cases, it can be even longer and takes months! For the following simulation, it was assumed that the infection lasts 30 days. The conducted research showed that an infectious person can spread the bacteria to around 10 people per infection (beta). As a starting value, it was assumed that 474 people had already been infected in the previous year and are currently recovered. Furthermore, it was assumed based on estimates that four people are currently infected as the initial or starting value. [1]

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N = 8000000 # Total population of Austria
I0, R0 = 4, 474 # infected and recovered, I0 and R0.
S0 = N - I0 - R0 # Everyone else, S0, is susceptible to infection initially
beta, gamma = 10, 1/30 # Contact rate = beta / recovery = gamma
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As can be seen in *Figure 1 TB with no medical interventions*, if the state does not regulate the containment of these bacteria, around 350.000 people can be infected within a year. It should be mentioned here that these are simulated values, which fortunately do not occur in reality.

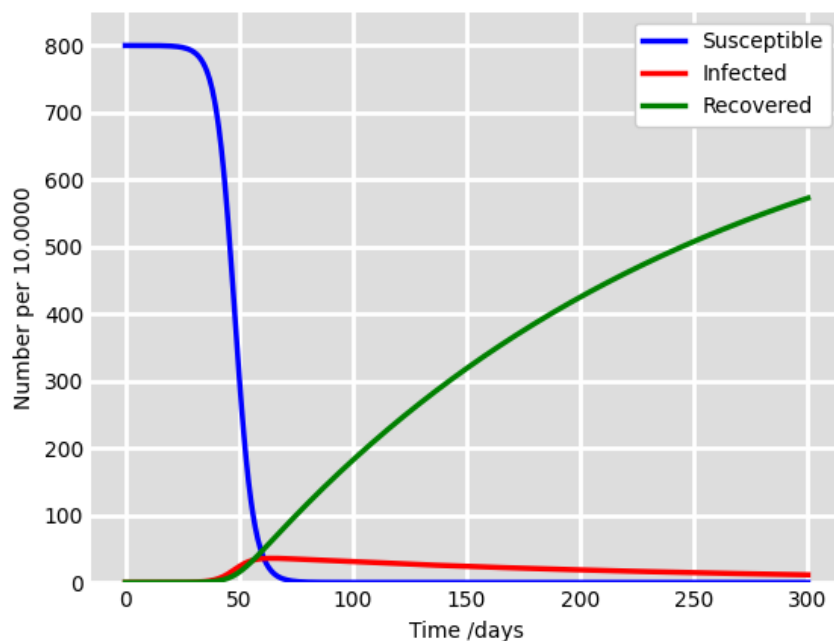


Figure 1 TB with no medical interventions

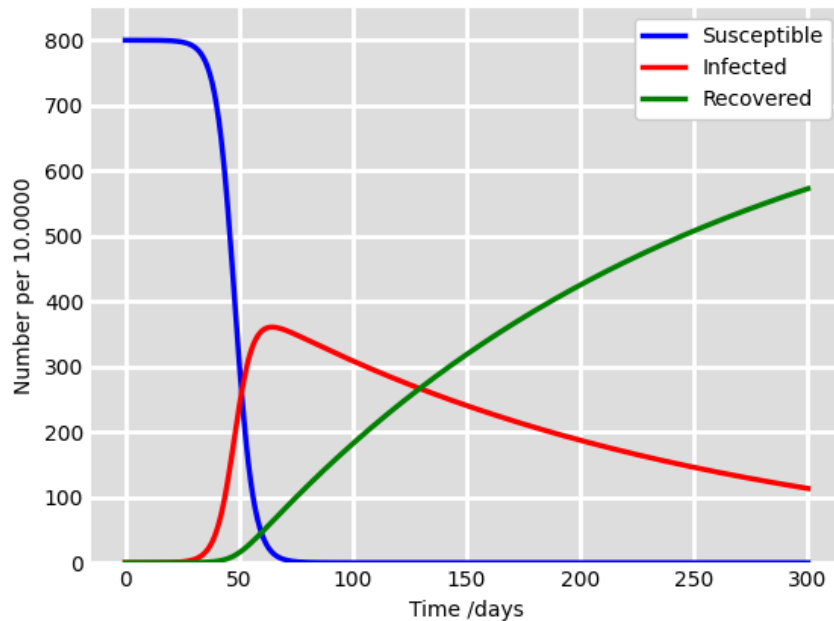


Figure 2 TB with no medical interventions (Infected: Number per 1.000)

Figure 2 TB with no medical interventions (Infected: Number per 1.000) represent the course of TB without any medical intervention. For demonstrative reasons, the “infected” line represents the persons which will get infected multiplied by 1.000 within a year. Therefore, the highest peak is at around 350 → $350 \times 1.000 = 350.000$ people might get affected. A complete “infection” of the whole population does not take place because sufficient immune protection is built up after about two months. Nevertheless, TB can mean far-reaching consequences for the population and the healthcare system if an uncontrolled outbreak prevails.

How is TB transmitted and what precautions can be taken?

In the case of open pulmonary tuberculosis, patients excrete the pathogens mainly when coughing and sneezing. In the process, aerosols get into the air and can then be inhaled by other people. Whether infection occurs depends, among other things, on how long and intensive the contact with the infected person was and how susceptible the person is to infection. In Central Europe, transmission through food such as raw milk is largely ruled out, as bovine tuberculosis is largely contained in these countries and will be therefore not considered for further simulations.

What are the symptoms?

- Fever
- Cough
- Sweat and exhaustion
- In later stages bloody sputum

How can it be detected?

- Antibody test on the skin
- Blood test
- X-Rays
- Direct bacterial detection

According to the Infection Protection Act, any tuberculosis requiring treatment must be reported as soon as possible to the competent health authority. This then identifies the close contacts (such as family members, friends etc.) and determines in which period and in which cases an infection could have taken place. [2]

The environmental investigations lead to the fact that the contact rate β can be significantly reduced because the infected person needs to be isolation. Therefore no further „danger“ emanates from him/her of transmitting this type of bacteria. Besides limiting the rate of contact, an essential point is a support provided by medication. Proper administration of medication can reduce recovery time by more than 50 percent. [3]

Which interventions can be made and what parameters are affected by those?

1. Wearing face masks → contact rate β will be reduced
2. Isolation → contact rate β will be reduced
3. Antibiotics' → recovery time after an infection and also the contact rate gets reduced (β and γ getting smaller) [4]

1. Medical intervention (face masks)

Data on face masks and TB are scarce, as existing studies have often considered the combination of several interventions. However, it can be assumed that when face masks are worn, the contact rate can be reduced by up to 60% (five people getting infected from one person). This assumption is also supported by the data from different diseases, where face masks were considered. It was assumed, compared to the Corona pandemic, that face masks would be worn in public facilities and public transport. [5] [6]

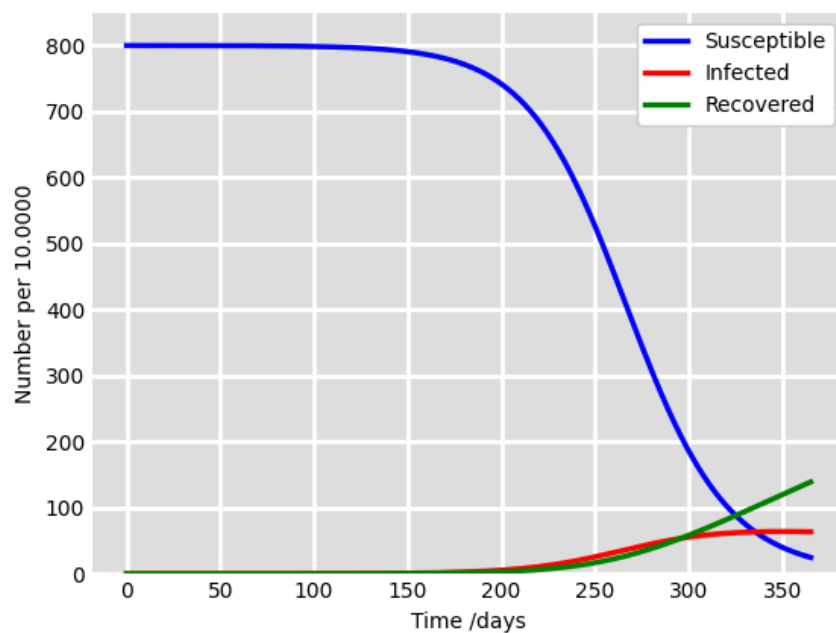


Figure 3 TB with face masks

Findings

Just wearing face masks has a drastic effect on spreading these bacteria. As can be seen, the incidence of infection is greatly reduced and a maximum of 50.000 (infected multiplied by 1.000) people could be infected. Only for a small percentage of the population does TB pose a threat (0.63 %). However, a big problem is that people can be infectious for up to 30 days and spread the bacteria over a long period of time. Therefore, interventions which are reducing the recovery time (γ) must be applied.

2. Medical intervention (Medication)

In the previous simulation, it was still assumed that no proper medication is used for the treatment of TB. This was taken into account in the following example. Adequate treatment with medication has the consequence that especially the recovery time is strongly reduced, and persons are not contagious to their environment for so long.

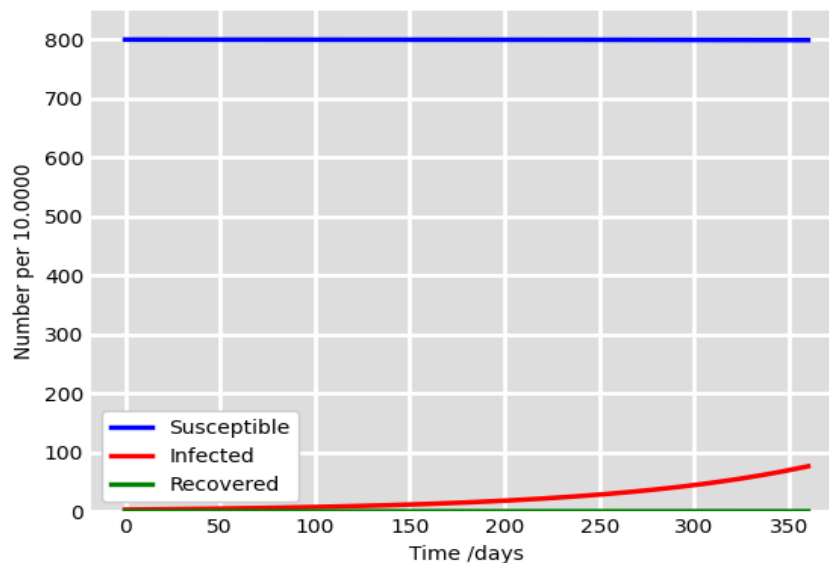


Figure 4 TB with medication

Findings

The following drugs are used nowadays in the treatment of TB: Isoniazid, Rifampicin, Ethambutol and Pyrazinamide. [7] The proper use of medication has a significant impact on the spread of these bacteria. On average, it can be assumed that these medical interventions reduce the recovery time by 50 up to 80 percent. Some studies have also shown that infected persons are no longer contagious and cured after only 10 days. [8] Gamma was therefore reduced from 30 to 15 days for the simulation. Besides the shortened recovery time (gamma), taking medication has a positive influence on how the bacteria are spread to other persons (beta). The simulation clearly shows that just wearing masks and taking TB medication properly has a drastic effect on the incidence of infection. The red line represents the number of infected persons within one year. (Multiplied with 10 because of demonstrative reasons) Due to the drastic reduction in the recovery time, only about 1.000 people can be infected.

3. Medical Intervention (Medication, Obligation to report and isolation)

The following three aspects are state of the art in the treatment of TB today: Medication, mandatory reporting and isolation from one's environment for a certain period of time. For further simulation, the current restrictions in the containment of these bacteria have been used. If a person is diagnosed with TB, they must be placed in isolation immediately. Furthermore, so-called contact tracing is carried out and relatives and work colleagues are contacted. Only when three independent samples of the sputum are free of pathogens, the contact person is released from isolation. [2] This means that a person is much less likely to infect those around him or her, as the individual can only leave the isolation if there is no danger from the infected one. The analysis of the current data showed that due to such restrictions it can be assumed that one to two people will be infected by a positive TB person. Furthermore, it must be taken into account that in most cases the body manages to fight the pathogens successfully or to render them harmless at an early stage by encapsulation. Thus, tuberculosis only actually breaks out in about five to ten percent of those infected.

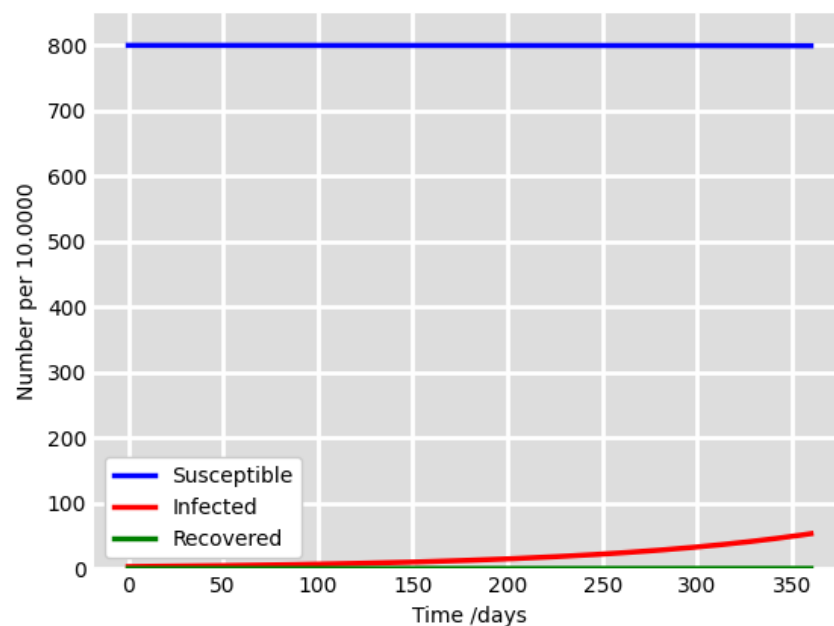


Figure 5 TB with medical interventions and restrictions

Findings

Analysing the results of the simulation, it is clear that national restrictions and proper drug treatments have a significant impact on the containment of these bacteria. For the calculation, it was assumed that an infected individual will spread TB to a maximum of 1.5 people (beta) and the recovery time is 12 days (gamma). Due to demonstrative aspects, the red line needs to be multiplied by 10. This means that a maximum of 500-600 people can be infected in Austria within one year.

This result is almost identical to the data from the past. Austria recorded a total of 569 infections in 2017, 482 in 2018 and 474 in 2019. [1] The marginal deviation is due to the fact that the essential factors such as beta and gamma are based on average values from different studies. Furthermore, factual data from the WHO and medical journals were also taken into account. Therefore, it is not possible to transfer these values and aspects 100 percent to Austria. In conclusion, it can be seen that TB in Austria cannot lead to any dangerous situation. Compared to other infectious diseases such as flu, TB is much less contagious.

Short Summary

- Without any restrictions and medical treatment, TB can infect close to 350.000 people per year in Austria.
- Without medication, the recovery time (gamma) is up to 30 days!
- Wearing face masks reduces the total number down to 50.000 per year in Austria.
- Proper medication reduces recovery time down to 10-15 days.
- Medication and national restrictions have a major impact!
- Contact rate gets reduced down to 1,5 due to isolation and obligation to report
- The combination of isolation and medication showed the best result
- Only a maximum of 500-600 individuals can be affected per year in Austria with this combination!

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