SEX AND AGE GROUP DIFFERENCES IN THE SPREAD OF TUBERCULOSIS IN INDONESIA: AN AGENT BASED MODELING APPROACH

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Abstrak

Tuberculosis (TB) is a serious contagious disease. Numerous research outside of Indonesia found that incidence of TB vary among different age groups and sex. This highlights the importance of research evaluating whether the spread of TB in Indonesia also differs by age group and sex. Especially considering data and information of the number and distribution of TB cases are very limited in Indonesia, as it requires certain expertise and large cost for data collection. Agent Based Modelling (ABM) is a tool that can be used to model epidemic spread. ABM has an advantage in describing structured epidemiological processes involving human behaviour and local interaction. Therefore, this study used ABM to enhance the understanding of the spread pattern of TB in Indonesia. The data used to form the model are from the publications of the Indonesia Ministry of Health, Statistics Indonesia, and WHO as from 2018 to 2020 .The study results confirmed that at national level, TB incidences varied among different age groups and sexes. It is also revealed the need for further study on the spread of TB in the age group under 15 years. It is expected that these findings can be useful for TB control program in Indonesia.

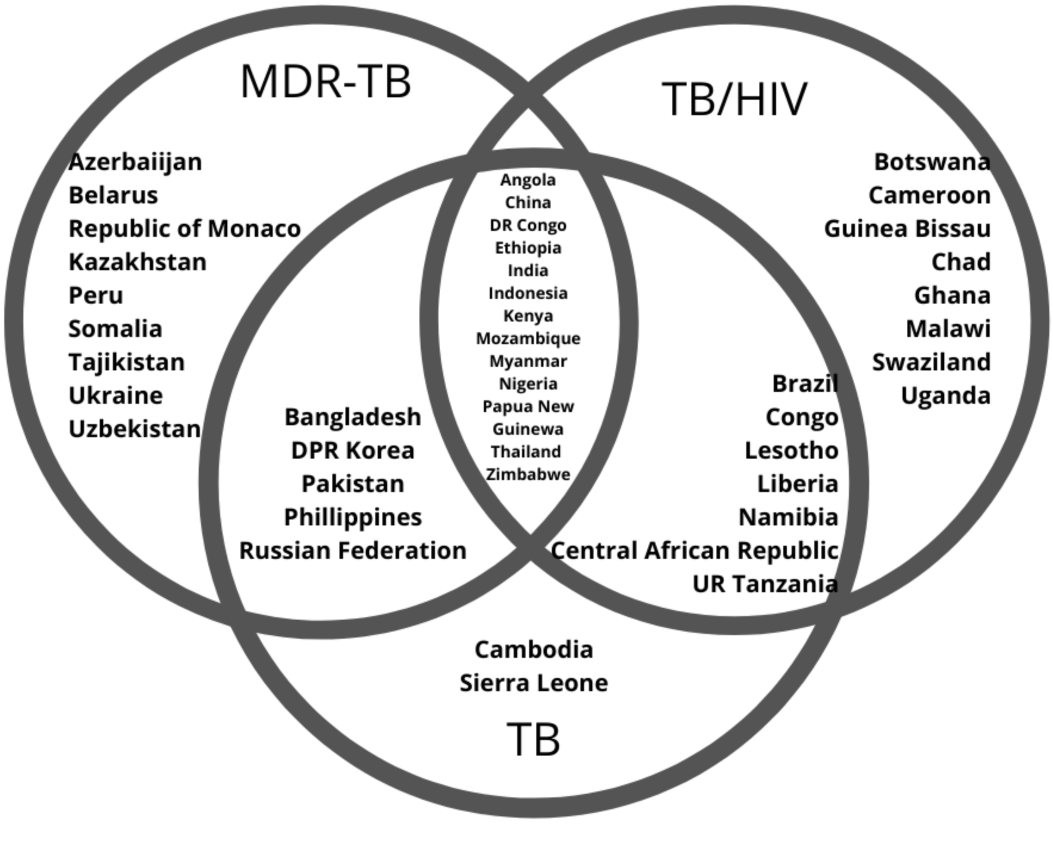
Keywords: Tuberculosis, Agent-Based Modeling, Age Group, Sex, Indonesia

INTRODUCTION

Tuberculosis is a disease caused by bacterium Mycobacterium Tuberculosis and often attacks the lungs of the sufferer aand followed by a severe cough, fever, and a heavy feeling in the chest. (Fogel, 2015; WHO, 2020). Commonly, people with tuberculosis have two kinds of conditions, latent (hidden) infected conditions and active infected conditions (Institute of Medicine (US), 2001). *Tuberculosis* or TB can spread from person to person through the air, therefore TB spreads very quickly.

In 2018, It is known that a quarter of the world's population have infected with the bacteria that causes TB. (WHO, 2020). Based on the publications of the World Health Organization, TB is included in the top 10 diseases that cause death worldwide. Due to its wide spread and high number of cases, TB is classified as a pandemic (*Global Pandemic | TB Alliance*, 2022). It needs special attention for the entire population of the earth. Therefore, the United Nations has decided on TB eradication, and targeting in 2030 as part of the Sustainable Development Goals (SDGs).

The WHO report in 2019 shows that Indonesia is included in the 14 countries with a high burden of TB, together with China, India, Nigeria and other developing countries, especially for the Southeast Asia region (Figure 1). In 2018, it is estimated that there are 842,000 TB cases and around 32% of those cases have not been reported in Indonesia (Kemenkes RI, 2018). Indonesia also included in the group of countries with high cases of Multi-drug-resistant TB (bacterial resistance to at least two types of anti-TB drugs). In addition, Indonesia also has high active TB and HIV positive cases at the same time. With the high cases of TB, MDR-TB, and being positive for TB and HIV simultaneously, Indonesia is classified as one of the 30 countries with a heavy TB burden (WHO,



source: WHO, 2020

Figure 1. High Burden Countries by TB, TB/HIV, and MDR-TB According to WHO 2016-2020

2019). This indicates that serious action is needed for Indonesia to immediately deal with TB.

TB can affect anyone, regardless of ethnicity, gender, and social status (Rajagopalan, 2001). However, several studies have shown that cases of morbidity and mortality due to tuberculosis are more vulnerable in the elderly population (Negin et al., 2015; Rajagopalan, 2001; Schaaf et al., 2010). In addition, the data show that more male are sick with TB (WHO, 2019; Horton et al., 2016).

The number of cases of TB disease among elderly population is due to the difficulty of detecting TB. This is due to the weak immune system of the elderly population (Schaaf et al., 2010; Negin, 2015). Data from the BPS shows that in 2020 in Indonesia around 14.8% of the population are people with an age of more than 55 years. In addition, based on WHO data in its publications, it shows that more adults and the elderly are exposed to TB. This indicates that special attention is needed for the elderly population to avoid and treat TB (WHO, 2020).

Several studies and publications also show that gender has an effect on the incidence of TB (WHO, 2020; Horton *et al.*, 2016; Mangngi, 2019). The difficulty of detecting TB in the elderly population and the large number of TB cases in the male population, are a challenge in seeing and determining the distribution of TB cases in the elderly population and the differences by sex. The ability to collect TB data through survey is very limited, as more capital and specific expertise are needed than usual survey. In addition, collecting TB data using surveys is difficult, especially in Indonesia. One of the reasons is that there are many symptoms of diseases in the elderly population may lead to a miss-diagnosis.A method that can be used to model TB cases is Agent Based Modelling (hereinafter is called ABM). Pappalardo *et al.*in 2019, for instance, they successfully made an extension for ABM named Universal Immune System Simulator (UISS) which is applied to large number of disease cases to analysis tuberculosis – immune system dynamics. In Indonesia, there have been studies that used ABM for TB cases too, such as that conducted by Gema Wahyu Saputra, Budhi Irawan, and Purba Daru Kusuma in 2018. In addition, there were also studies using ABM in a structured age population conducted by Graciani Rodrigues, Espíndola and Penna, in 2015. Agent-based simulations can be used to obtain information about TB cases in the elderly population based on gender in Indonesia, such as for estimating TB cases, viewing a graph of the development of TB cases, or even comparing TB cases in the elderly and non-elderly population age. Agent-based simulation or also known as Agent Based Modeling (ABM) is a method that allows researchers to create, analyze, and conduct experiments from a model consisting of a number of agents. (Siagian and Prasojo, 2021). By simulating, some information or data can be retrieved without conducting a more expensive survey or census. The results of the simulation are expected to provide an overview of the distribution of TB in the population that classified to the age group and the differences by gender. Taking this into account, further research on the distribution of TB by sex can be carried out using the ABM method. To date there are no studies related to TB that classified to the age group in Indonesia and the differences by gender using the ABM method. Therefore TB research by age group difference and the differences according to sex in Indonesia is needed with the help of the ABM method. This research may help to analyze how the condition of TB in Indonesia, so the government and society can aware and act correctly to reduce the TB cases in Indonesia.

With the existing problems, there were several questions related to the ABM research and its application in cases of TB Indonesia and the difference between ages and the sexes. Some of the questions are as follows: 1) How is the ABM model for the spread of TB cases in Indonesia; 2) How is the description of TB cases among the sick, under treatment and cured population in Indonesia; 3) How are TB cases different between male and female for elderly population in Indonesia; 4) Is the model formed valid or not?

To answer the existing research questions, the objectives of the research are described as follows: 1) Build an ABM model for the spread of TB in Indonesia. 2) Conducting simulations with the ABM model to get an overview of TB cases in the sick population, under treatment, and cured from TB in Indonesia. 3) To determine the pattern of TB in the age groups and the differences by gender. 4) Validate the ABM Model for TB spread in Indonesia.

DATA AND STUDY AREA

ABM processed using Netlogo software. Netlogo is free and open source software developed by Northwestern University. In addition, the ABM model used for the formation of ABM in TB cases in the age groups and its differences according to gender in Indonesia, is a development of the contagion model.

For the validation stage of the model which is formed, it is done by comparing the results of the ABM model that is formed with the published official statistics. The output of the ABM results are in the form of graphs and statistics such as percentages and summaries. From the graphs and percentages generated through the ABM, then it compared with the published statistics.

The variables or statistics that are inputted or used before the simulation process is carried out are as follows:

1. Number for total population in the model (Indonesian population scaled).
2. Rate of TB infection per 100000 population
3. The time length of treatment which carried out.
4. Sick TB rate per 100000 population.
5. Rate under treatment per 100000 population
6. Rate treated per 100000 population
7. Simulation time (in years)
8. Aids-rate Indonesia
9. Diabetes rate
10. Factors resistant to TB drugs
11. Abandon rate
12. Diabetes-factor
13. Risk Factor
14. Mean diagnosis delay
15. Correction factor

The variables obtained during the simulation process are as follows:

1. Movement (in the form of graphs) of the addition or decrease of agents with the status of infected, sick, under treatment and cured.

The variables obtained after the simulation process ends are as follows:

1. Prediction in the form of elderly population and non-elderly population based on sex with sick status.
2. Descriptive statistics of the elderly population and non-elderly population by sex with sick status

These data were collected from the publications of the Ministry of Health, BPS, and WHO from the latest publication, it comes from 2018 to 2020. In addition, the characteristics and behavior of agents regarding TB in Indonesia are adjusted to literature studies and publications from the Indonesian Ministry of Health and BPS. Information in the form of population and population structure is used to form an artificial population that resembles the characteristics of the Indonesian. So, a simulation is created that is similar to the real condition.

The number of agents is also adjusted to the population in Indonesia. Agents will be distinguished according to the status given, namely healthy, infected, sick, under treatment and cured. The movement of the agent will be simulated in two periods, namely 360 days and 720 days.

Supporting statistics are inputted on the interface of the ABM model which is made to resemble the situation or condition in Indonesia. Other supporting variables such as diabetes rate, Aids, abandon rate and others are obtained from publications from the Ministry of Health. Some variables or statistics are used at the back of the model or coding such as variable of proportion of the population suffering from TB according to gender and age. In addition, there are also probability for women and men to be infected with TB in

Indonesia. Counting the number of days for each agent to change status is also set on the back section or coding.

After the process of forming the ABM has been completed and the required statistics have been inputted, the model will produce output in the form of statistics of agent with sick status. The statistics generated are in the form of population movements with sick status during the simulation, according to age and gender. Then, the movement will be divided into elderly and non-elderly residents, as well as men and women. The elderly in this category are residents of population aged 65 years and over.

METHODOLOGY

ABM is a model with a bottom-up type, where the smallest units are agents who act according to the program that has been made. The characteristics of the agent are made according to the characteristics of the Indonesians. In this study, the ABM model used is an application or continuation of the ABM model on TB cases in Barcelona made by Julia Vila Guilera, Clara Prats, and Angels Orcau. Julia, et al. in his research formed the ABM model of TB epidemiology in Barcelona by considering the role of age, gender and origin of the population (Vila Guilera, 2017).

Agent-based modeling in its application is a model that uses a computer program to create a number of agents with programmed characteristics and behaviors. The purpose of ABM is to observe what will happen to the simulation progresses. The elements that make up ABM are a number of agents, rules or choices that agents will make (e.g.: move, get infected, die, etc.), interaction structures such as environment, and randomness.

The agents used in this study are imitation individuals from Indonesian population. Individuals have several attributes such as age group and gender. Each agent or individual will be given an order to interact with each other. From the interactions between agents, it can be seen how the virus spreads from agent to agent.

The basic model used to make the ABM for the spread of TB in Indonesia in the difference according age and gender is the contagion model. The contagion model is commonly used to model various problems such as the spread of disease, the spread of information, the spread of hoaxes, various health-related behaviors, and others. In this study, the contagion model was used to see the spread of TB disease in Indonesia. In addition, the type of epidemic model used in this research is SEIR (Susceptible, Exposed, Infectious, and recovered) model.

The first stage is a literature study to study the ABM and TB methods in Indonesia. To learn more about ABM, the website ccl.northwestern.edu/ provides and gives information related to ABM and the applications that support it, such as Netlogo. Furthermore, to deepen about TB in Indonesia using TB-related research and publications from related research.

The formation of the ABM model is divided into three main parts, the three main parts are: (1) *specification – formalization*, (2) *Modelling – Verification – Experimentation*, and (3) *Calibration – Validation* (Salgado and Gilbert, 2013). In the first stage is to reviews the terms of the theories that will be used to answer the research question and turn it into a mathematical or logical expression. The next step is the formation of the model with the help of the netlogo application. The final step is to test or validate the results of the model formed.

The first stage in this research is to collect related theories and studies regarding ABM and TB. The aim is to study and support the results of the research that will be obtained. In addition, from the theories and related research collected, research questions are obtained which will later be answered by establishing the ABM model. After the theories are collected, then they are changed or specified into a logical or mathematical form so that further steps can be taken.

The second stage in the formation of the ABM is modeling, verification, and experimentation. At this stage the thing to do is to change the logical or mathematical statements that have been formed in the previous step into a computer program. In this study using a computer program or Netlogo software. Then check the program that has been made. Whether there is an error or there is a discrepancy with the existing theory, this step is called verification. This is necessary because every time you run the program, you may get different results each time you run it. The snippets of the coding used in coding section is as follows:

```
set get-sick-rate 0
set from-infected-to-healthy from-
   infected-to-healthy + 1
ask patch-here [ set num-healthy num-
   healthy + 1]
die
]
; Different sickening probabilities are
   assigned depending on the age of the
   infected turtles. 50% of the 0-5 y.o
   infected will sicken, 15% for the 5-15
   y.o and 3% for the 15 y.o plus.
;
if age <= (5 * 365) [set age-factor 1]
if age > (5 * 365) and age <= (15 * 365)
   [set age-factor 1]
if age > (15 * 365) [set age-factor 1]
if gender = 1 [set gender-factor 1]
if gender = 0 [set gender-factor 1]
```

P.S: The code section is too long to be display, here are little bit of part that has been used.

Calibration and Validation is the last stage of the formation of the ABM model aims to test or validate the model that has been formed. According to Bianchi, Cirillo, Gallegati, & Vagliasindi, (2007) in the research of Salgado & Gilbert in 2013 stated that there are three ways to validate the ABM model, namely Descriptive output validation, Predictive output validation, and Input validation. In this study, we use descriptive output validation, which matches the output of the computational results of the ABM model with available data, in this case statistics from publications from the Indonesian Ministry of Health and WHO.

RESULT AND DISCUSSION

Formation of ABM Model

Theoretical models can be defined as the development of theories that aim to explain a situation or phenomenon, some of which can even do forecasting. In social science, model is a mathematical abstraction or simplification of a social process. Some of the purposes of modeling are to understand, measure, and estimate variable(s). Based on the type, models in social science are divided into three; statistical models, analytical models, and agent-based models (Balietti, 2012; Lee, 2012). One of models that can be used in social science is ABM. ABM uses computer programs to form a number of agents that have certain characteristics and behaviors, in order to observe what will happen over time. ABM has begun to be widely used in many fields, one of which is social science, such as in the case of disaster evacuation simulations, forest fires, and even the spread of diseases such as Covid-19 or TB

TB is a fairly complex epidemic disease. In its spread, TB is influenced by many factors such as demographics, health, environment and others. As an effort to understand TB cases in Indonesia, an ABM model for TB cases was created that focuses on TB cases in the Indonesian population and the differences according to gender and age groups.

In this study, the ABM model used is a development or continuation of the ABM model on TB cases in Barcelona made by Julia Vila Guilera, Clara Prats, and Angels Orcau. Julia, et al. in his research formed the ABM model of TB epidemiology in Barcelona by considering the role of age, gender and origin of the population (Vila Guilera, 2017). What distinguishes this research from (Vila Guilera, 2017) research is that this study tries to form a model with the characteristics of the Indonesian region and focuses on the elderly population and their differences by gender. This is deemed necessary considering that the formation of the ABM model for TB cases in Indonesia is still relatively rare, especially for research that focuses on the elderly population and the differences based on gender.

In general, the steps to form the ABM model are divided into three steps (Salgado and Gilbert, 2013). The first step is to collect related theories and research on TB cases, especially in Indonesia. Next is modeling, which is changing the logical statement obtained from the first step into a computer program, in this study a logical statement or logic change is made into the Netlogo programming language. The last step is model validation, the goal is to determine whether the model formed is appropriate or resembles the original state, in this study validation is carried out by comparing the output of the model that has been formed with statistics from the publication.

Theories and related research are collected to form a solid basis in the formation of the model. The result of the theory and related research collected is that in the case of TB it is influenced by many factors. Several factors influence TB and are used in the model such as diabetes, aids, immunity to TB drugs, patients who ignore treatment, the average time the patient is checked for illness, the length of time to recover from TB, and other risk factors. In addition, the number of TB infection, illness, treatment period, and recovery from TB per 100,000 population is also used, simulated population data and simulation time are also used.

Through a study of theories, related research, and publications obtained, it is known the statistical values used as the basis of the model. The statistics obtained are used in two different sections, the first in the coding section and the second in the interface section. The proportion of the Indonesian population by age and the proportion of the population by age with TB and the proportion of the population with TB by sex are used in the coding section. Others statistics are used in the interface section according to Figure 2.

In the interface, we can input the required numbers directly. The figures required have been adjusted to the conditions in Indonesia in general. For the part of the population infected with TB, for example, a value of 25,000 per 100,000 population is entered, this is based on the WHO publication which states that a quarter of the world's population is infected with the TB virus. (WHO, 2020) Other numbers such as diabetes factor, abandon rate, immunity and other factors are numbers in percent. As for the length of treatment, the mean delay-diagnosis has a unit of time, which is counted in days.

The second stage in the formation of the ABM model is modeling, verification, and experimentation. At this stage, the transformation of logical and mathematical statements into a computer program is carried out. This research converts statements into programs that can be read by the ABM processing application, Netlogo. The statements are converted to the form of a computer program in the coding section. The basic coding used was sourced from Juvia's research for TB cases in Barcelona, which was then adapted to the situation and conditions in Indonesia. After the coding section has been successfully

Figure 2. ABM interface section for TB cases in Indonesia

completed, then it is connected to the interface section that has been made according to Figure 2. If both the coding section and the interface have been connected, then running is done to see if there are any discrepancies or errors that occur. When no discrepancies or errors are found, the formation of the model can proceed to the next stage, namely model validation.

Model validation is a process or stage of proof of a model that can be considered appropriate (Tsioptsias, Tako and Robinson, 2016). In this study, the validation stage was carried out at the end of the research section. Validation is done by matching the results of the model that has been made with published statistic. In addition, the ABM model that is formed also has an output in the form of simulation results for cases that occur in residents with certain age groups, as well as cases that occur in female and male population. The resulting output is then matched with the latest publications published by the WHO. If the results of the output are matched with the publications, then the model that have been made can be concluded to be valid, so that it is good to use.

Simulation with ABM Model for Agents with Sick, Under treatment, and cured Status

The simulation is carried out in two time spans, one year and two years. The purpose of the simulation is to see the movement or get an overview of TB cases with the characteristics of the population in Indonesia. To see the description and movement of TB cases in Indonesia, a line graph with three main lines used. The line for agents with sick status (red), sick plus undertreatment (blue), and cured (yellow). The results of the simulation carried out are in accordance with the following figure.

The results of the simulations are shown in Figure 3. and it show interesting results. Based on the graph in Figure 3. it can be seen that there was a change from TB cases which initially increased to decreased in the first 25 days. This was because the ABM modeling was done setting the average duration of diagnosis for 25 days, meaning that the average duration of diagnosis was 25 days. On average, agents will perform tests or treatment after 25 days feel they have TB symptoms. This is based on the cough classification which states that an acute cough will heal in less than two weeks and the conditions or characteristics of the Indonesian population in taking treatment. (Kasi and Kamerman-Kretzmer, 2019). The reason for determining the average examination time based on the length of cough is because one of the symptoms of TB disease is chronic cough (Loddenkemper, Lipman and Zumla, 2016). In addition, from the simulation results its gained information; that the length of time the agent reports the disease or the length of time to detect a sick agent are affecting the movement of TB. This indicates that the faster it is to detect agents with TB disease, the faster the decrease in TB cases will occur. This is supported by the paper of Frank, R which states that the earlier the diagnosis is made, the higher the chances of recovering early (Frank, 2015).

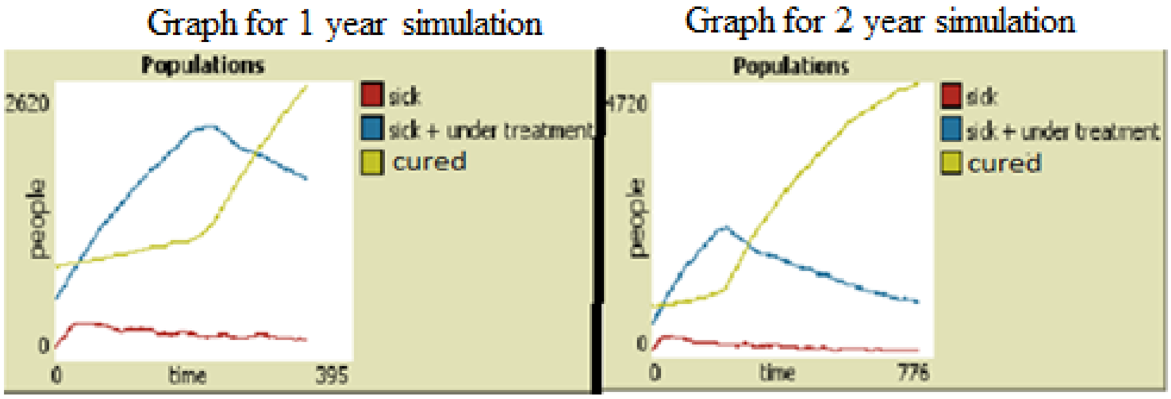


Figure 3a. ABM Simulation of TB Cases in Indonesia for 1 year (left)
Figure 3b. ABM Simulation of TB Cases in Indonesia for 2 year (Right)

Another thing that can be seen is that there is an increase in agents with under treatment status, and a decrease in cases of agents with sick status, as well as an increase in agents who have cured or been treated after the first 25 days of the simulation. The increase in the graph of agents with under treatment status is due to the change from agents with sick status to under treatment. In addition, as previously discussed, the increase in agents with under treatment status is due to the average agent inspection time. That is 25 days. The graph increase for agents with under treatment status occurred from the 25th day to the 200th day. This drastic increase in the graph indicates that facilities are needed to support the needs of patients during TB treatment during this time span. Then after day 200 there will be a decrease in the graph of agents with under treatment status followed by an increase in the graph of agents with cured status

Another finding that can be seen from the model simulation results is an increase in the graph of agents with cured status and a decrease in the graph of agents with sick and under treatment status after the 200th day. This is based on the change in status from agents with sick and under-treatment status to cured. In other words, agents who are under treatment have recovered or cured from TB disease. The increase in this graph occurs because usually individuals will fully recover from TB if the individual routinely and disciplined follows treatment procedures during the treatment period for 160 days to 185 days or 6 to 7 months. (Kementerian Kesehatan, 2016; Terefe and Gebrewold, 2018).

The simulation is divided into three phases. The first phase occurs in the first 25 days, in this phase there is an increase in the agent with sick status. Furthermore, in the second phase what happened was a decrease in agent with sick status followed by an increase in agent with under treatment status, in this phase it occurred after the 25th day to the 200th day. The third phase is the phase where there is a decrease in agents with under treatment and sick status, on the contrary there is an increase in agents with cured status, this phase occurs after the 200th day, indicating that many individuals have successfully recovered from TB disease.

The Pattern of TB Distribution by Age Groups and the Differences by Gender

The pattern of TB distribution is known to vary by age group. It is known that the adult population is more exposed to cases of illness due to TB. This is in line with the results of the ABM simulation, with the following results below.

The results of the simulation for TB cases in Indonesia as shown in Figure 4. It shows the differences between TB cases according to age

Groups. The highest cases occur in the population aged 5-14 years, this could

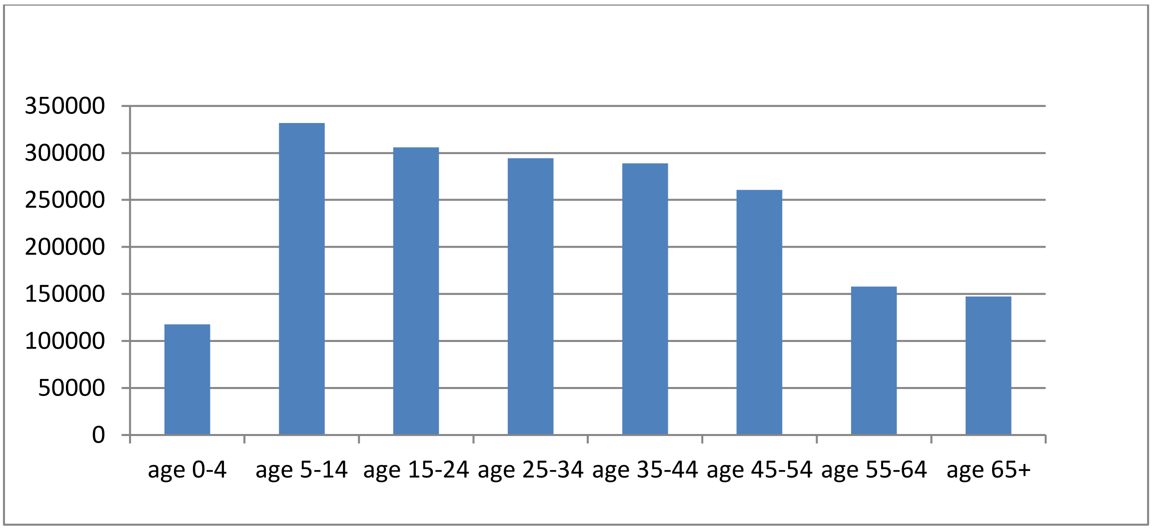


Figure 4. TB Cases by Age Group From Results of Simulation

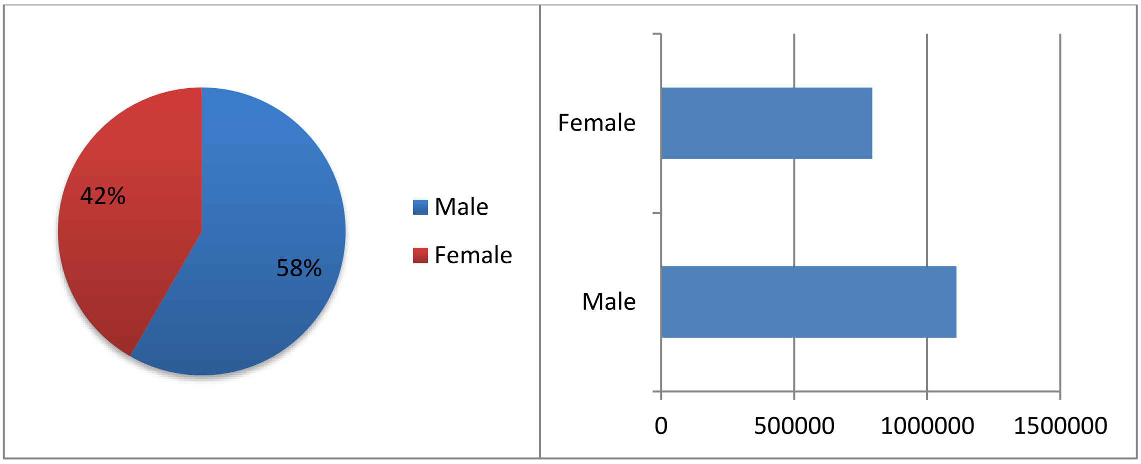


Figure 5a. Agent With Sick Status by Gender (Percentage) (Left)
Figure 5b. Agent with Sick Status by Gender (count) (Right)

be because the population under the age of 20 years has a greater chance of getting sick when infected (Vila Guilera, 2017). In addition, the population aged over 65 years does not appear to be too high compared to other age groups, but still needs to be considered, because mortality is more vulnerable in the elderly population (Negin, Abimbola and Marais, 2015). The productive age group when combined, has a large number of cases, this could be due to the large number of contacts made to other people in public places such as offices, etc.(Tuite *et al.*, 2017). Another thing besides the different age groups in the TB distribution pattern is gender. More TB cases occur in men than women (Horton *et al.*, 2016). This is in line with the results of the ABM simulation as shown in the following graphs and charts.

The results of the ABM simulation in Fig. 5a and Fig. 5b shows that cases of TB disease that occur in males are higher than females. In addition, the simulation of the ABM that was carried out showed that men had about 16% of cases of illness due to TB compared to women. This is in line with Mangngi's research which states that men have a greater tendency to get TB disease than women (Mangngi, 2019). The results of the ABM simulation also show that differences in TB cases by gender occur in all age groups, which is visualized in the following figure.

The ABM modeling has shown that agents with male attributes get more TB

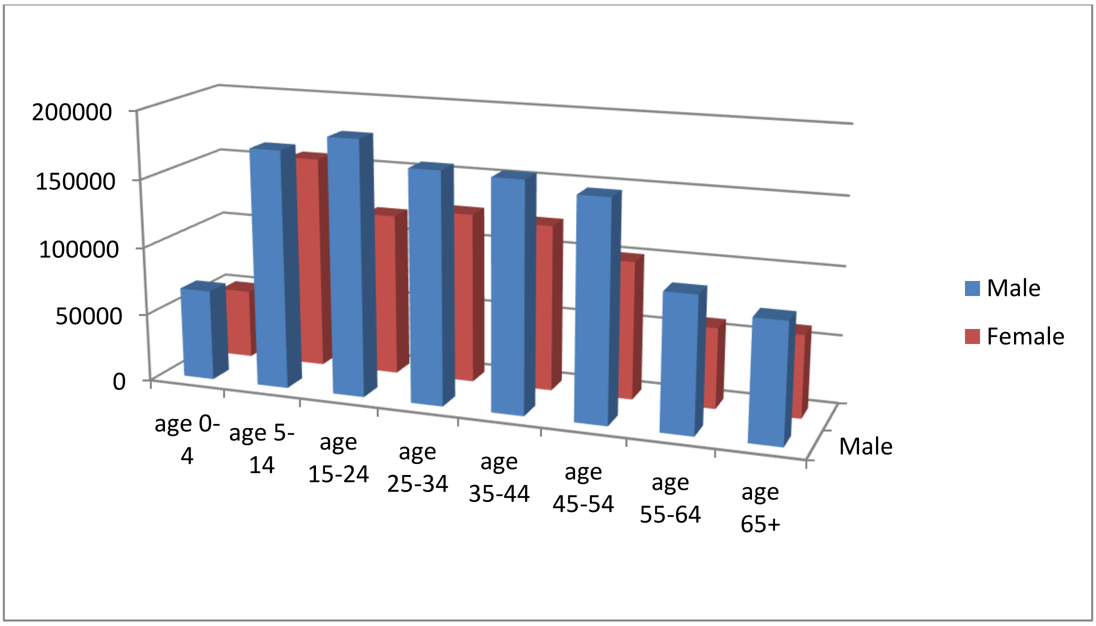


Figure 6. TB Disease Cases by Age Group and Gender

cases in all age groups. Men tend to have a lifestyle that makes them more susceptible to exposure to TB. In addition, men's lungs tend to be larger than women's, so the possibility of harboring TB-causing bacteria is higher. (Yates and Atkinson, 2017). More attention needs to be given to TB that occurs in men and people in the age group over 65 years. Although graphically the cases that occur in this age group are not too high compared to cases in other age groups, cases of TB disease in the elderly population, especially men, remain a frightening specter considering the resilience of the population of this age group is not too strong and the style of The life of men tends to make health vulnerable, followed by disease complications that may occur. Comparison of TB disease cases in the population aged over 65 and the differences by sex can be seen in more detail in the following figure.

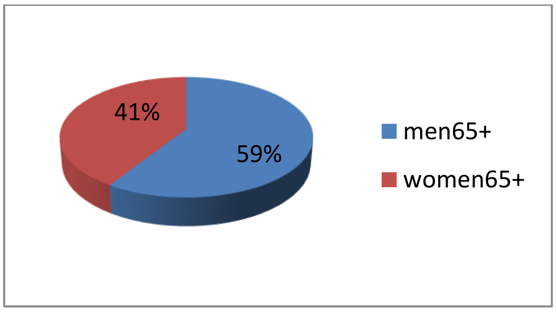


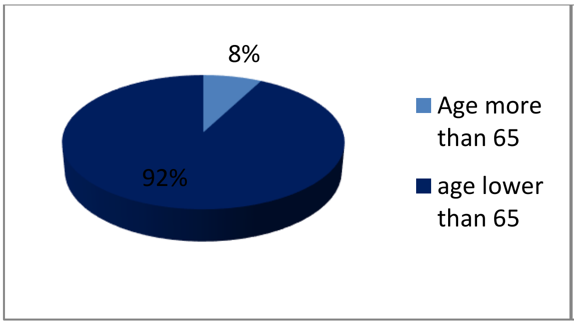
Figure 7. Percentage of Population Sick of TB in the Elderly by Gender

The graph from the ABM simulation shows that in the elderly population the percentage of TB cases is much more experienced by men. Overall it is almost the same as TB cases in general, only in the elderly the percentage of TB disease for men is greater, namely 59% compared to 58% overall. Some studies say this could be influenced by hormones and immunity possessed by men, especially those who are over 65 years old. (Neyrolles and Quintana-murci, 2009; Negin, Abimbola and Marais, 2015).

Model Validation

Validation is carried out to determine whether the ABM model formed is a good model, so that the results of the simulation can be trusted. In this ABM model for TB cases in the elderly and the differences by gender, validation was carried out by matching the results from simulations with publications. The results that will be matched to the ABM model formed are the percentage of the elderly population compared to the non-elderly population who are sick with TB.

Broadly speaking, the results from the simulation and publications are different, although the difference is not too far, this result is shown in Figure 8. The simulation shows that the elderly population who is sick with TB is around 8% of the total. Meanwhile, the results of WHO publications show that in 2019 around 11% of the elderly population was sick with TB. When compared to the published results with simulations for TB sick cases in the elderly population, there is a difference of 3%. According to the researcher, this figure is not too large, considering that in general, for inferential analysis, an error significance level of 5% is used.



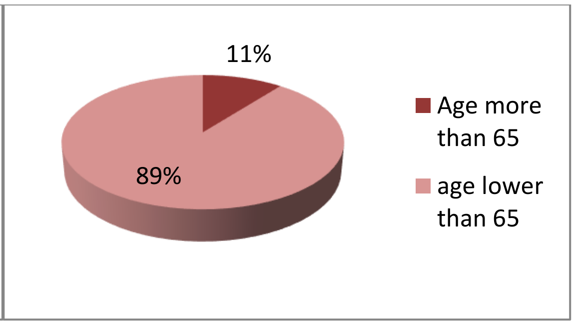
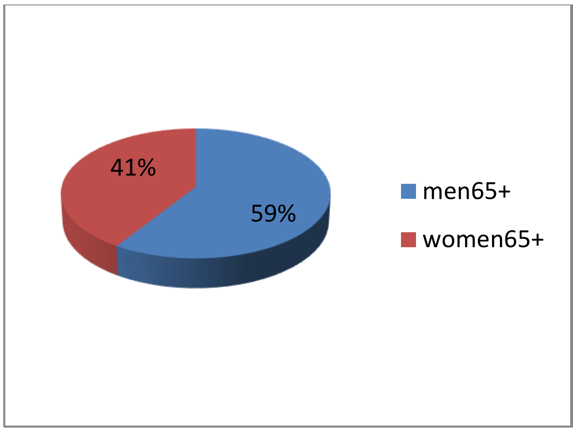


Figure 8a (Left). Comparison of the Percentage of TB Sick Cases by Age Group (Simulation)
Figure 8b (Right). Comparison of the Percentage of TB Sick Cases by Age Group (Publication)



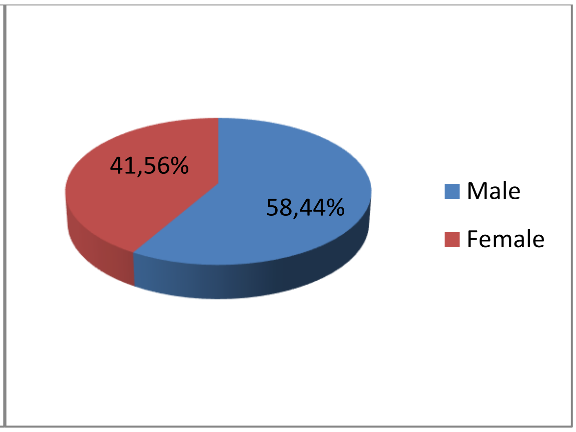


Figure 9a (Left). Pie Chart Percentage of Illness Due to TB in the Elderly by Gender.(Simulation)

Figure 9b (Right). Percentage of Illness Due to TB in the Elderly by Gender.(Simulation) (Publication)

Validation was also carried out on the results of TB cases according to gender, in addition to age group. Validation is carried out in the form of matching the percentage of simulation results and publications, the same as before. From the results of matching simulations and publications that have been made, the following results are obtained.

The results of simulations and publications for sick TB cases are shown in Figure 9a and Figure 9b. show very similar or close to the same results. Based on the results of the publication, the male population with TB in 2019 was 58.44%, while the results from the simulation showed a result of 59%. With a difference of less than 5%, it can be said that the results of the ABM model are close and reasonable when compared to the results from publications.

In general, although not exactly the same, the results of the ABM simulations have similar characteristics or similarities with the original results, when compared to publications conducted by WHO. For cases of TB disease in the elderly population, the ABM simulation results show lower results than the published results. Meanwhile, the results of the ABM simulation on the population by gender gave very similar results to the results of WHO publications, with a difference of even less than 1%. With these results, it can be concluded that the ABM model formed is a valid model, so the results can be used.

It should be admitted, this research still has many limitations. In this research, model simulations are run for national coverage, whereas, it is well understood that the characteristics between regions in Indonesia, such as between provinces, between districts/cities are very different. This is one of the limitations of this research. It is better in the future, the ABM model that is formed to be more specific for each region that wants to be studied more deeply about TB cases. In addition, this research was conducted only by visually descriptive analysis and focused on the elderly population, even though there are still many things that can be done with the formation of the ABM model that has been made. The statistical sources used in the formation of this model come from various sources such as WHO, BPS, and the Indonesian Ministry of Health because the sources obtained are different, this is a limitation of the research. Some other shortcomings are the use of statistics on the part of the population, in the ABM model that is formed the population used is a reduced-scale population statistic, this is a shortcoming considering that the more appropriate the model is with its original state, the better the model is. The validation part is carried out only by comparing the similarities visually and not statistically, so that in terms of conclusions it is still not good enough. These are the limitiation of the research, but at least this research can be used as an initial model to be continued or refined in the further research.

CONCLUSION AND SUGGESTIONS

The ABM model for TB cases in Indonesia was successfully formed with the help of the netlogo application. The simulation results show that TB cases are divided into three phases. From the simulation results, it can also be seen that for the elderly population, TB cases are not too high compared to other age groups. In addition, the results of the simulation show that male agent are more exposed to TB disease more than female agents. The validation of the ABM model that has been carried out shows that there is a similarity between the simulation results and the publications data, which means the model can be used.

Some suggestions that can be obtained from the research results are as follows. For the government, to keep focus on eliminating to TB cases in Indonesia, especially for the elderly population and the male population. This is considering the results of the ABM simulation which shows that men are more susceptible to TB disease. So, it is important for men to be more aware of TB because TB can be very dangerous for the body if not treated immediately. As the simulation results show the largest cases among population aged less than 15 years. Further research can focus on TB cases among population with the age group less than 15 years, further research can focus on TB cases among population aged less than 15 years. In addition, further ABM modeling on TB cases that can be carried out is by using the latest statistics and be more specific at province level or regional.

REFERENCES

Balietti, S. (2012) *Agent-Based Modeling*. doi: 10.1007/978-3-642-24004-1.

Fogel, N. (2015) 'Tuberculosis: A disease without boundaries', *Tuberculosis*, 95(5), pp. 527–531. doi: 10.1016/j.tube.2015.05.017.

Frank, R. (2015) 'IMPORTANCE OF EARLY DIAGNOSIS AND TREATMENT OF LARYNGEAL TUBERCULOSIS', pp. 3–6.

Graciani Rodrigues, C. C., Espíndola, A. L. and Penna, T. J. P. (2015) 'An agent-based computational model for tuberculosis spreading on age-structured populations', *Physica A: Statistical Mechanics and its Applications*, 428, pp. 52–59. doi: 10.1016/j.physa.2015.02.027.

Horton, K. C. *et al.* (2016) 'Sex Differences in Tuberculosis Burden and Notifications in Low- and Middle-Income Countries: A Systematic Review and Meta-analysis', *PLoS Medicine*, 13(9), pp. 1–23. doi: 10.1371/journal.pmed.1002119.

Institute of Medicine (US) (2001) Tuberculosis in the Workplace, National Academies Press (US).

Kasi, A. S. and Kamerman-Kretzmer, R. J. (2019) 'Cough', *Pediatrics in Review*, 40(4), pp. 157–167. doi: 10.1542/pir.2018-0116.

Kemenkes RI (2018) 'Tuberkulosis (TB)', *Tuberkulosis*, 1(april), p. 2018. Available at: www.kemenkes.go.id.

Kementerian Kesehatan (2016) 'Info data dan informasi Tuberculosis 2016', p. 12. Available at: http://www.pusdatin.kemkes.go.id/folder/view/01/structure-publikasi-pusdatin-info-datin.html.

Lee, I. (2012) 'Agent Based Modeling - YouTube'. Available at: https://www.youtube.com/watch?v=XB4e-3nws1g&ab_channel=MartinHilbert.

Loddenkemper, R., Lipman, M. and Zumla, A. (2016) 'Clinical aspects of adult tuberculosis', *Cold Spring Harbor Perspectives in Medicine*, 6(1), pp. 1–26. doi: 10.1101/cshperspect.a017848.

Mangngi, M. P. (2019) 'Faktor Risiko Umur, Jenis Kelamin Dan Kepadatan Hunian Terhadap Kejadian TB Paru Di Puskesmas Naibonat Tahun 2018'. Available at: http://repository.poltekeskupang.ac.id/1936/.

Negin, J., Abimbola, S. and Marais, B. J. (2015) 'Tuberculosis among older adults - time to take notice', *International Journal of Infectious Diseases*, 32, pp. 135–137. doi: 10.1016/j.ijid.2014.11.018.

Neyrolles, O. and Quintana-murci, L. (2009) 'Sexual Inequality in Tuberculosis', 6(12). doi: 10.1371/journal.pmed.1000199.

Pappalardo, F. *et al.* (2019) 'An agent based modeling approach for the analysis of tuberculosis - Immune system dynamics', *Proceedings - 2018 IEEE International Conference on Bioinformatics and Biomedicine, BIBM 2018*, pp. 1386–1392. doi: 10.1109/BIBM.2018.8621355.

Rajagopalan, S. (2001) 'Tuberculosis and aging: A global health problem', *Clinical Infectious Diseases*, 33(7), pp. 1034–1039. doi: 10.1086/322671.

Salgado, M. and Gilbert, N. (2013) 'Agent based modelling', *Handbook of Quantitative Methods for Educational Research*, pp. 247–265. doi: 10.1007/978-94-6209-404-8.

Schaaf, H. S. *et al.* (2010) 'Tuberculosis at extremes of age', *Respirology*, 15(5), pp. 747–763. doi: 10.1111/j.1440-1843.2010.01784.x.

Siagian, T. H. and Prasojo, A. P. S. (2021) 'Agent-Based Modelling Pada Studi Kependudukan: Potensi Dan Tantangan', *Seminar Nasional Official Statistics*, 2020(1), pp. 1032–1040. doi: 10.34123/semnasoffstat.v2020i1.591

Tb Alliance (no date) *Global Pandemic | TB Alliance*. Available at: https://www.tballiance.org/why-new-tb-drugs/global-pandemic (Accessed: 27 January 2022).

Terefe, A. N. and Gebrewold, L. A. (2018) 'Modeling Time to Recovery of Adult Tuberculosis (Tb) Patients in MizanTepi University Teaching Hospital, South-West Ethiopia', *Mycobacterial Diseases*, 08(01), pp. 1–6. doi: 10.4172/2161-1068.1000258.

Tsioptsias, N., Tako, A. and Robinson, S. (2016) 'Model validation and testing in simulation: A literature review', *OpenAccess Series in Informatics*, 50(6), pp. 6.1-6.11. doi: 10.4230/OASIcs.SCOR.2016.6.

Tuite, A. R. *et al.* (2017) 'Stochastic agent-based modeling of tuberculosis in Canadian Indigenous communities', *BMC Public Health*, 17(1), pp. 1–12. doi: 10.1186/s12889-016-3996-7.

Vila Guilera, J. (2017) 'Analysis and individual-based modelling of the tuberculosis epidemiology in Barcelona. The role of age, gender and origin.', (May). Available at: https://upcommons.upc.edu/handle/2117/107446.

WHO (2020) *Global Tuberculosis Report*, *BMC Public Health*. Available at: https://ejournal.poltektegal.ac.id/index.php/siklus/article/view/298%0Ahttp://repositorio.unan.edu.ni/2986/1/5624.pdf%0Ahttp://dx.doi.org/10.1016/j.jana.2015.10.005%0Ahttp://www.biomedcentral.com/1471-2458/12/58%0Ahttp://ovidsp.ovid.com/ovidweb.cgi?T=JS&P.

Yates, T. A. and Atkinson, S. H. (2017) 'Ironing out sex differences in tuberculosis prevalence', *International Journal of Tuberculosis and Lung Disease*, 21(5), pp. 483–484. doi: 10.5588/ijtld.17.0194.