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Model of Hospital Infectious Waste Control on Site Pandemic COVID-19 Padang City Based on Dynamic Systems

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Abstract

Padang City is the epicenter of the spread of COVID-19 in West Sumatra, with the highest cases of COVID-19. As a result of which, infectious waste in hospitals has increased. This study aims to build a model for controlling hospital infectious waste in Padang City based on a dynamic system and formulate scenarios and policy recommendations for controlling hospital infectious waste in Padang City based on a dynamic system. This type of research is quantitative with a system-dynamic approach. The research location is in Padang City from March 2020 – July 2022. Descriptive data is presented in the form of tables and graphs. Dynamic system modeling used Powersim Studio 10. The infectious waste control model for hospitals in Padang City based on the dynamic system of the COVID-19 pandemic case obtained simulation results from a population of 909,040 people in Padang City, there were 57.38% of the population exposed, 10.06% positive for COVID-19, 71.9% self-isolation, 28.1% hospitalized, and 1.27% death. Vaccination simulation obtained 85% vaccination 1, 69.69% vaccination 2, and 11.73% booster vaccination. From the hospital infectious waste simulation, there was an increase in the generation of infectious waste by 100% compared to before the pandemic. Model validity test obtained AME declared valid (< 10%) (4) Policy recommendations for controlling infectious waste in Padang City hospitals based on the dynamic system of the COVID-19 pandemic case are with the vaccination scenario, health protocols, and PSBB, will optimistically reduce positive COVID-19 cases, treatment and the generation of infectious waste in Padang City hospitals.

Introduction

West Sumatra Province is included in the province with the highest number of confirmed positive cases of COVID-19 in Indonesia. Data on the spread of COVID-19 as of Monday, April 11, 2022, totaled 103,653 positive confirmed cases of COVID-19, with 2,328 deaths in West Sumatra (Website Corona Sumbar, 2022). Padang City is the epicenter of the spread of COVID-19 in West Sumatra because it has the highest number of COVID-19 cases of all districts/cities in West Sumatra. Data on the spread of COVID-19 in Padang City as of April 3, 2022, as many as 7,305 people were confirmed positive for COVID-19, with 42 deaths (DKK Kota Padang, 2022).

Based on the case data above, there is a strong possibility that the increase in hospital patients' number correlates with the increase in medical waste generation (Sarkodie & Owusu, 2021b), especially infectious waste characterized as material suspected of containing pathogens that can trigger disease (Yong et al., 2009). Even though a COVID-19 infectious medical waste control system already exists, the most important thing is that the

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COVID-19 infectious medical waste control system must be implemented comprehensively. Control is not only carried out internally in the hospital, but also in all components, both policy stakeholders and the community. The ultimate goal is to reduce the number of COVID-19 cases so that COVID-19 infectious waste decreases (Sharma et al., 2020).

Regarding this problem, the dynamic system is considered appropriate for solving this problem because the system-dynamic method has a close relationship with the feedback structure representing the causal loop (causal circle) (Chaerul et al., 2008; Forrester, 1994). The expected results can make emphasis and control infectious medical waste. From the case data above, this research uses a system-dynamic approach to describe the hospital's infectious medical waste system.

This dynamic system method deals with trend questions or a dynamic pattern of behavior of a complex system. It is a method used to assist in decision-making to find policies and decisions that are profitable and can be implemented properly within a certain period and time. The dynamic system is a methodology used to study and manage complex feedback systems. It can be a useful analytical tool for evaluating the impact of policies in the short or long term. The ultimate goal of creating a simulation model is to validate the model and scenario decisions. Validation aims to make the model close to the original and credible system. The model's credibility can be stated from the verification and validation. It can be simulated using computer-assisted predictions to see results quickly (Hasan et al., 2015).

The dynamic system is effectively used on systems that require a good level of data management in large quantities. Based on the flexibility, it will provide convenience in carrying out the process of model formulation, determining model boundaries, model validation, policy analysis, and model application. Stages in the system dynamic approaches, namely: Identification and problem definition, system conceptualization, model formulation, model simulation, model verification and validation, policy analysis, policy implementation (Mundra & Hirijanto, 2020).

Method

The location of this research purposively was at Dr. Rasyidin Regional Public Hospital, Universitas Andalas Hospital, Semen Padang Hospital, Reksodiwirjo Hospital, and Dr. M. Djamil Central General Hospital because it is a COVID-19 referral hospital in Padang City. The population of this study is all infectious waste generated at the COVID-19 referral hospital and residents of Padang City. The types of data used in this research are primary and secondary data. The primary data source was obtained through the questionnaire given to 11 Sub-District Heads throughout Padang City via the Microsoft Forms platform. The questionnaire was validated by 2 validators who were experts in their fields. They are Dr. dr. Linda Rosalina, S.Ked, M.Biomed as head of the COVID-19 Task Force, and Dr. Zikri Alhadi, S.IP, MA as a public policy expert.

Secondary data sources were official publication documents and literature as well as official records from city government agencies consisting of the Padang City BPS, the Padang City Health Office, the Padang City COVID-19 referral hospital, and the Central Laboratory for Diagnostic and Infectious Disease Research, Faculty of Medicine in Universitas Andalas. The collected data and information were analyzed quantitatively. Quantitative analysis is used to compile the needs of each stakeholder and the infectious waste control strategy. Quantitative data processing is done either manually or with the help of the R Studio computer program. Quantitative analysis is used to explain causal relationships between variables in the model. The secondary data obtained became the material for system conceptualization producing a causal loop diagram. The conceptual system was developed into a quantitative model in the form of a stock-flow diagram using Powersim Studio 10 to simulate (Mundra & Hirijanto, 2020).

The stages in creating a model using the system-dynamic methodology is begin with understanding and reviewing the system. In this step, the boundaries of the model studied must first be defined before the model is studied. The boundary separates the processes that cause expressed internal tendencies from those that represent exogenous influences. The model boundaries will describe the analysis scope and then, based on the issues addressed. It will include all causal interactions related to the issue. The following steps are to develop a causal diagram (causal loop) of the system. After the model boundaries can be defined, a diagram structure interacting feedback (feedback loops) can be formed. The feedback structure is a model building block expressed through closed circles. In this study, the formulation of infectious waste control policies in the Padang City COVID-19 referral hospital was formulated in the form of a Causal Loop Diagram in FIGURE 1 below.

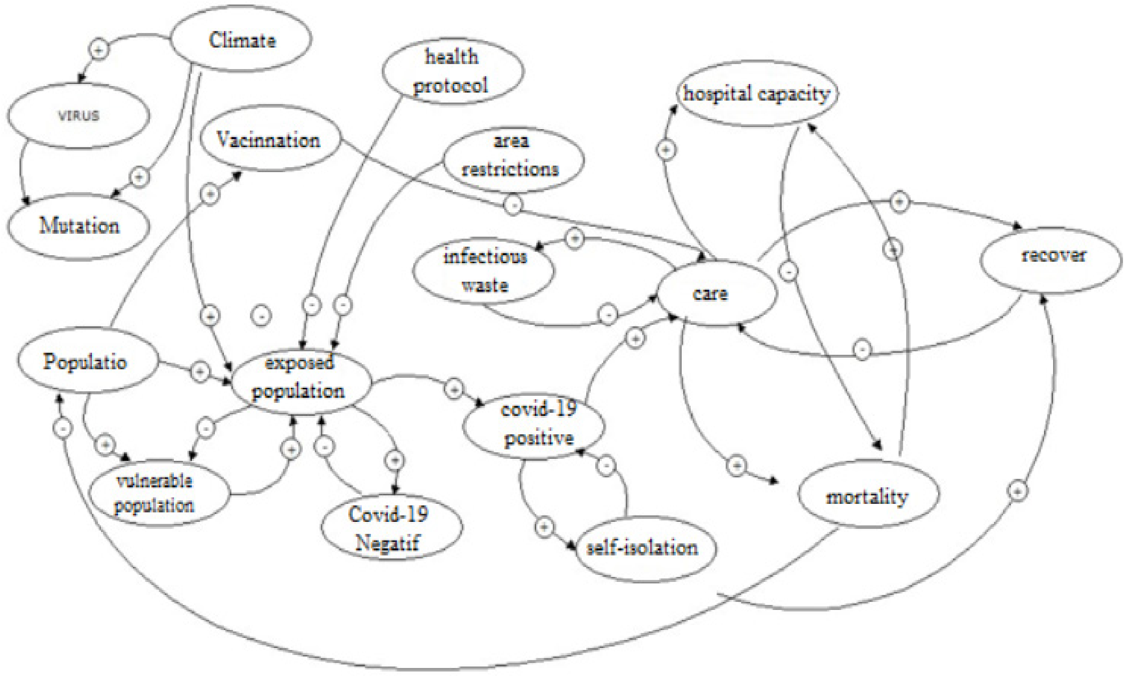


FIGURE 1. Causal Loop Diagram of COVID-19 Infectious Waste Control
Source: Variable Processing Results with Powersim Studio 10

Based on the causal circle, level and rate diagrams of the system are constructed. It will describe various interactions/relationships between entities in the system. The development of level and rate diagrams is carried out with the help of the Powersim software. Develop a model of the system formulated as a representation or abstractions of all interactions occur in the system under study. After an explicit model of a problem is formulated, a series of tests is carried out on the validity of the model, and at the same time, gain an understanding of the internal tendencies of the system. Model validation is carried out in several validation stages, including: (a) Theoretical validation of the first model structure (CLD = Causal Loop Diagram), (b) Validation of the second model structure data (SFD = Stock Flow Diagram), (c) Validation of model behavior. In the model behavior validation stage, statistical tests of deviations and tests of average and variance deviation tests of the data are used. The average deviation test is the absolute means error (AME) test, which is the deviation (difference) between the average (mean) value of the simulation results and the actual value, which is calculated using the formula:

$$AME = \frac{|Si - Sr|}{Sr} X\ 100\ (\%) \qquad (a)$$

Description:
Si: average of simulated data
Sr: average of reference data
| | sign means the absolute price used to cancel the minus sign of the reduction result. Data declared to be valid from the results of calculations with a dynamic system when the AME is below 10%

The variance deviation test is the absolute variance error (AVE), namely the deviation of the simulated variation value against the actual calculated using the formula:

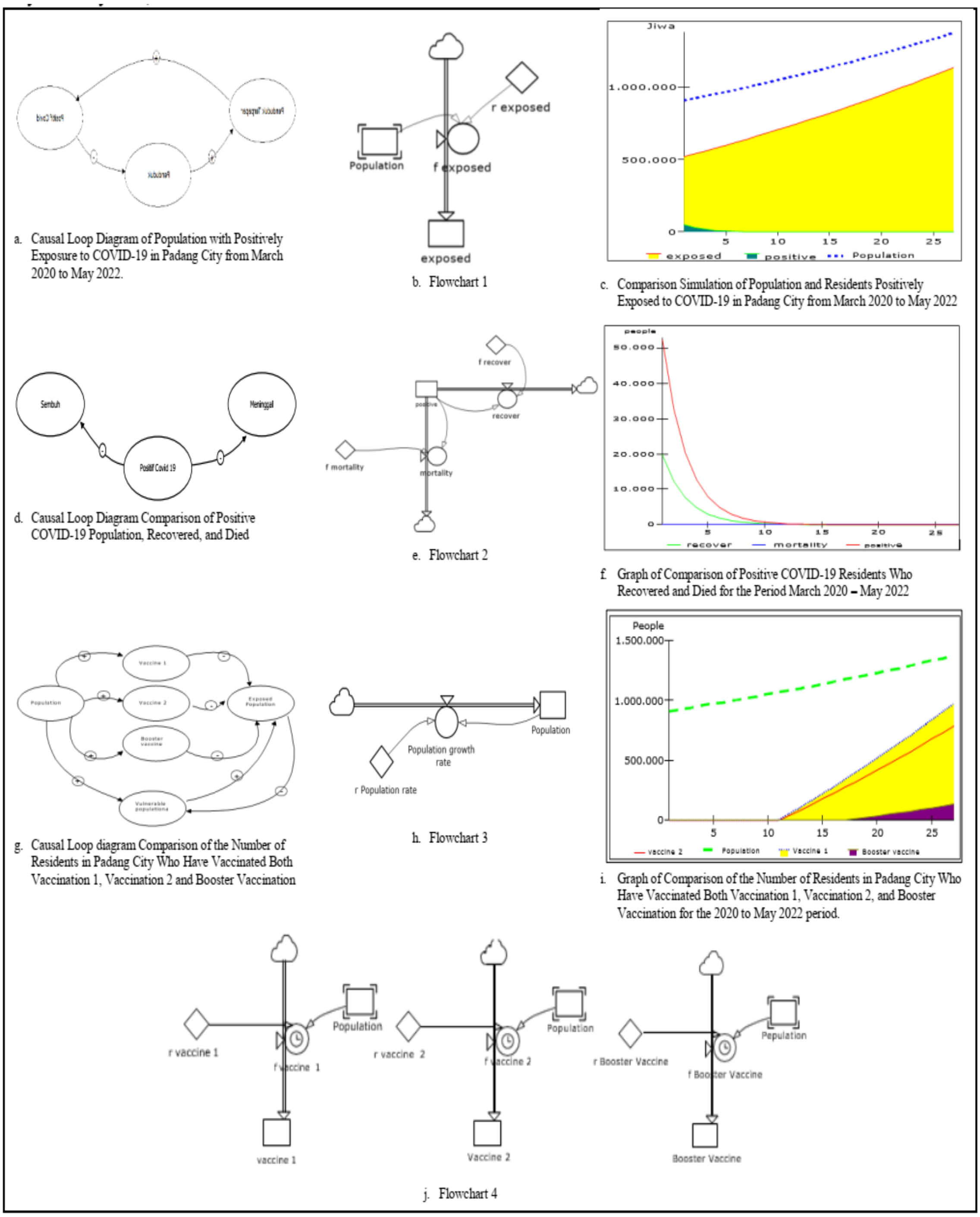
$$\text{AVE} = \left[\frac{(Ss - Sa)}{Sa}\right] \quad \text{(b)}$$

Description:
Ss: ((Si – Si)2N) = Simulation value deviation
Sa: ((Sr – Sr)2N = Actual value deviation

Then do a simulation to assess the impact of parameter changes on the studied system. Based on the simulation results, appropriate policy recommendations will be produced to achieve system objectives, namely policy recommendations for controlling hospital infectious waste in Padang City in the case of the COVID-19 pandemic.

Result and Discussion

Based on research done to find out how the control model is obtained with the stages in making a model that uses a dynamic system, can be seen in FIGURE 2.



a. Causal Loop Diagram of Population with Positively Exposure to COVID-19 in Padang City from March 2020 to May 2022.

b. Flowchart 1

c. Comparison Simulation of Population and Residents Positively Exposed to COVID-19 in Padang City from March 2020 to May 2022

d. Causal Loop Diagram Comparison of Positive COVID-19 Population, Recovered, and Died

e. Flowchart 2

f. Graph of Comparison of Positive COVID-19 Residents Who Recovered and Died for the Period March 2020 – May 2022

g. Causal Loop diagram Comparison of the Number of Residents in Padang City Who Have Vaccinated Both Vaccination 1, Vaccination 2 and Booster Vaccination

h. Flowchart 3

i. Graph of Comparison of the Number of Residents in Padang City Who Have Vaccinated Both Vaccination 1, Vaccination 2, and Booster Vaccination for the 2020 to May 2022 period.

j. Flowchart 4

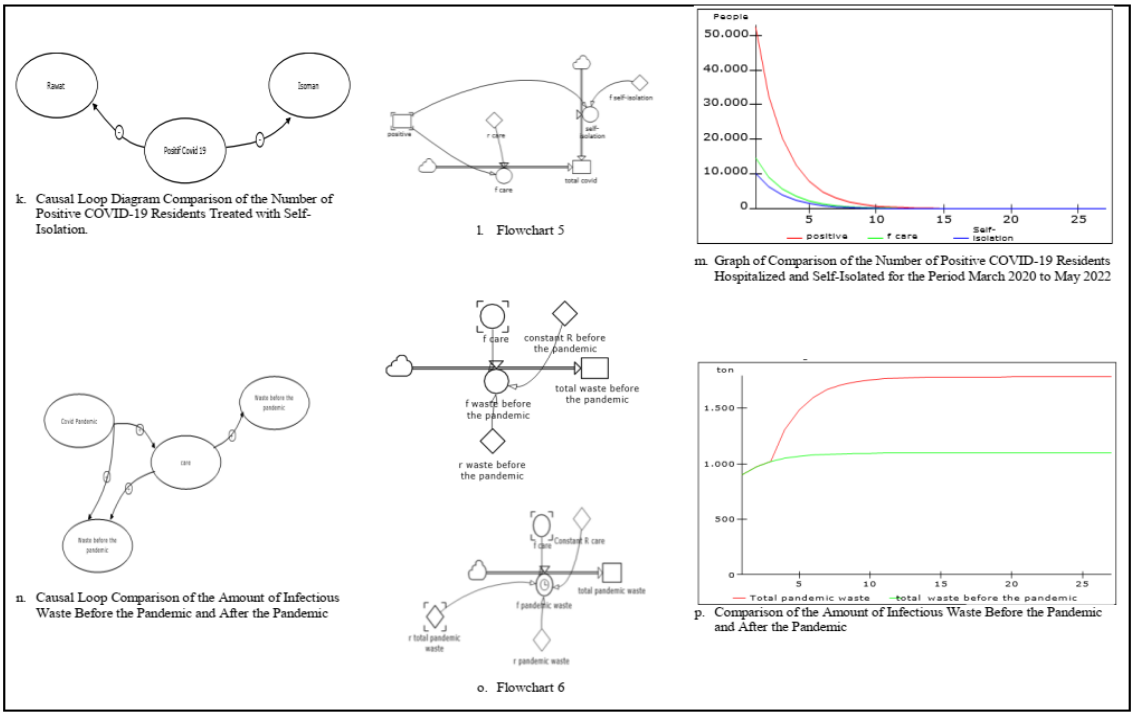


FIGURE 2. Causal loop diagrams, flowcharts, and graphical models Padang City Hospital Infection Waste Management Model Based on Dynamic Systems

Stock Flow Dynamic (SFD) Model for Infectious Waste Control at Padang City Hospital Based on a Dynamic System (COVID-19 Case) can be seen in FIGURE 3.

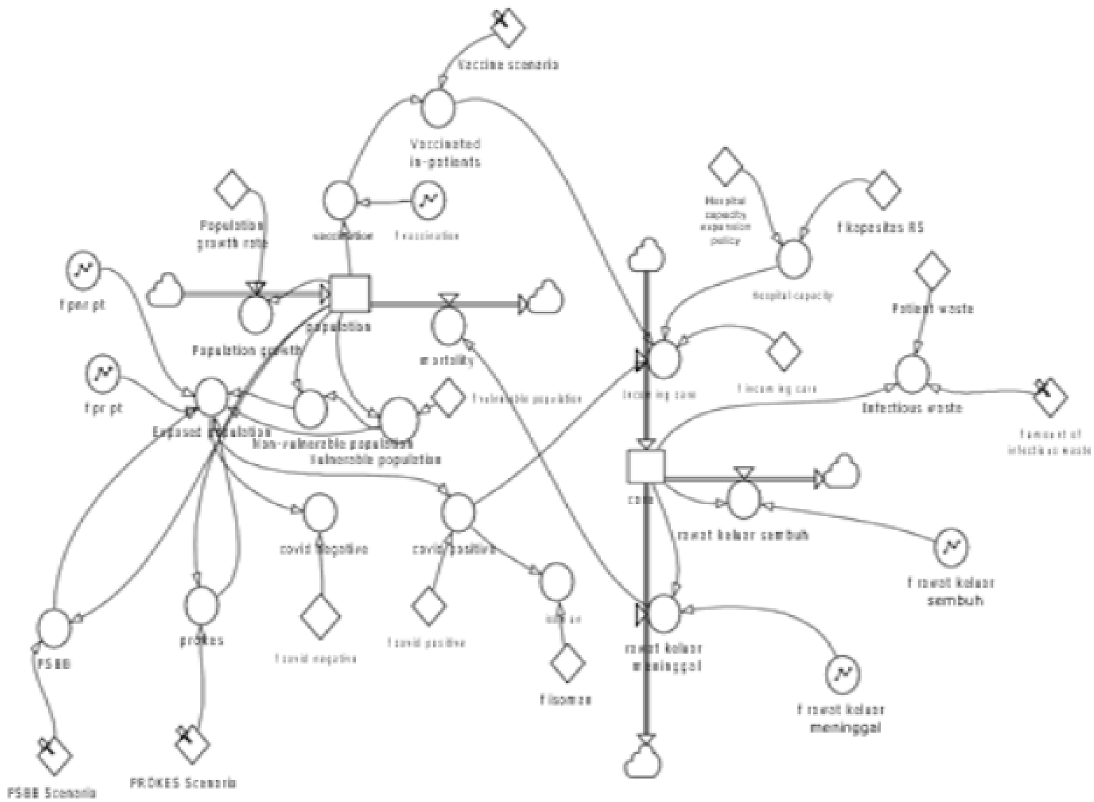


FIGURE 3. Stock Flow Dynamic (SFD) Infectious Waste Control Model for Padang City Hospital Based on Dynamic System (COVID-19 Case)

This SFD shows a series of all interrelationships to explain where infectious waste comes from. Explaining the number of residents in Padang City, the number of vulnerable residents, the number of exposed residents, and the number of positive COVID-19 sufferers. Then of the positive COVID-19 patients, some are self-isolating, and some are hospitalized. Those who are hospitalized led to an increase in infectious waste after the pandemic.

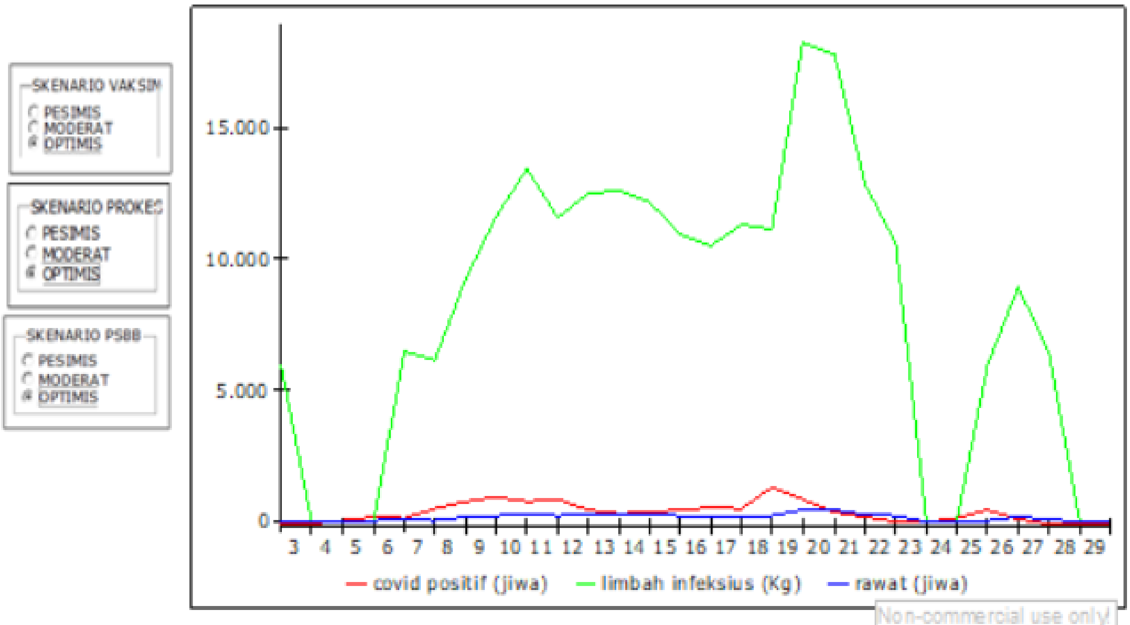


FIGURE 4. Policy Recommendations for Infectious Waste Control at Padang City Hospital Based on Dynamic Systems (COVID-19 Cases) with optimistic scenarios of vaccination, health protocols, and PSBB

From the scenario graph in FIGURE 4 above, the policy recommendations for controlling infectious waste at the Padang City hospital based on a dynamic system (the COVID-19 Pandemic Case) are obtained by having an optimistic vaccination scenario, an optimistic health protocol scenario, and an optimistic PSBB scenario that can suppress and reduce the positive number of COVID-19, the number of treatments and reduce the amount of infectious waste. Initially, the Coronavirus Disease 2019 (COVID-19) virus-infected animals, such as bats and camels. It then mutates and infects humans. This virus spread quickly and widely, resulting in a global pandemic continuing to this day. The COVID-19 virus spreads quickly from human to human through direct contact. COVID-19 can be transmitted in various ways, such as through droplets or liquid droplets coughed or sneezed, direct contact such as touching or shaking hands with a COVID-19 patient and touching objects contaminated with the COVID-19 virus, then hands touching mouth, ears, and eyes before washing hands (Sarkodie & Owusu, 2020).

An exposed population, more commonly known as a suspected case, is someone with a history of contact with a confirmed case of COVID-19 and has symptoms of acute fever with cough, anosmia, and ageusia. From the exposed population, there will be two possibilities to be tested positive and negative through the Rapid Diagnostic Test Antigen (RDT-Ag). Residents who test positive will undergo further tests through PCR testing. If the first examination is declared negative, it is carried out on the second day. If the results are positive, the patient is declared positive and recommended to be hospitalized according to the patient's management based on symptoms. In Padang City, from BPS 2021 data, with a population of 909,040 people, 57.38% were declared as exposed residents of the existing population and confirmed positive 10.06% of the exposed population. The number is measured by the vulnerability of the community, one of which is population density, where the denser, the greater the potential for exposure to the COVID-19 virus.

Based on the positive population, some people have recovered and died. Residents are said to have recovered from positive COVID-19 when they have received treatment according to the level of symptoms experienced depending on the infecting variant. Someone without symptoms needs time to recover faster than patients with mild, moderate, severe, and acute symptoms. All of the patients above can be declared cured if they meet the criteria for completion of isolation, and a statement letter for completion of monitoring is issued, based on the doctor's assessment at the health care facility where the monitoring was carried out or by the doctor in charge of the patient (KEMENKES RI, 2021). When the symptoms are severe and even acute, cannot be treated with hospitalization, and complications occur. It can cause the patient to die. Hosts of COVID-19 are humans, especially vulnerable groups who have low immunity. The physical environment of the COVID-19 virus is like poor environmental sanitation, the biological environment, for example population density, virus virulence, and the socio-cultural environment such as behavior, economic environment, and politic. Transmission of COVID-19 from person to person or level of mobility can be minimized by adhering to health protocols so that the vulnerability of an area is also influenced by the level of community compliance in implementing health protocols (Gandamayu et al., 2022).

In Padang City, 53,024 people recovered from a positive population of 10.06%, where the number of people who recovered was more than the number of positive residents in Padang City. It was happened due to the data on the number of recovered, included data from patients referred to all referred hospitals in Padang City. The number who died was 670 people (1.27%) of the positive population. The number of exposed residents is measured by the vulnerability of the community, one of which is population density, where the denser, the greater the potential for exposure to the COVID-19 virus. To reduce the risk of morbidity and mortality from COVID-19, an effective and safe vaccine must be administered quickly and widely to the public. However, the availability of vaccines itself is not enough to guarantee broad immunological protection, vaccines must also be accepted by both the health community and the general public. Vaccine hesitancy is a primary barrier to vaccine uptake and achieving community immunity, which is necessary to protect the most vulnerable populations. Depending on a variety of biological, environmental, and socio-behavioral factors, the threshold for herd immunity to Covid-19 may be between 55% and 82% of the population (Sanche et al., 2020).

Various kinds of COVID-19 vaccines used worldwide, tested for safety, and the results include Sinophram, Pfizer, AstraZeneca, Moderna, Jessen, and Sinovac (World Health Organization, 2022). Indonesia used various COVID-19 vaccines, including Sinovac, Moderna,and Pfizer. The vaccination has three stages. Namely vaccination 1, vaccination 2, and Booster vaccination. Vaccination 1 starts in early January 2021, vaccination 2 starts at the end of January 2021, and Booster vaccine starts in July 2021. Booster vaccines meant to increase immunity and be able to reduce risks for high-risk groups with comorbidities or groups with a high risk of exposure, such as the elderly and health workers (Jung, 2021).

In Padang City, with a population of 909,040 people, 85% have had vaccine 1, 69.69% have had vaccine 2, and residents that received booster vaccines are 11.73%. From the data above, many residents of Padang City have not been vaccinated and there has not been an even distribution of vaccines 1, 2, and Booster. It is due to various factors, one of which is the large number of people who still refuse to be vaccinated. The public's rejection of the COVID-19 vaccination occurred due to doubts and anxiety due to insufficient information about the COVID-19 vaccination, as well as a large amount of information circulating containing hoaxes that scared the public to vaccinate. It is hoped that the need for improved communication between the government and the community (Paul et al., 2020).

Residents confirmed positive for COVID-19 have various symptoms, ranging from asymptomatic, mild, moderate, severe, and acute symptoms, where generally asymptomatic patients are advised to self-isolate at home. For patients with mild symptoms, some are recommended to take home isolation, some are hospitalized, and patients who have moderate, severe, and even acute symptoms are recommended to undergo hospitalization. Especially for patients who are confirmed positive for COVID-19 with comorbid must receive intensive care at the hospital. COVID-19-positive patients with acute symptoms are usually comorbid patients, such as hypertension, diabetes mellitus, cardiovascular disease, chronic obstructive pulmonary disease, chronic liver disease, and cancer. Usually, the treatment and care need to be done more intensively because of the possibility of a high risk of failure. In Padang City, 52,492 people who are positive for COVID-19, 71.9% of whom are self-isolating and 11.73% hospitalized. It happens because many people who are self-isolating according to the symptoms experienced are mostly without symptoms and mild symptoms. Meanwhile, those who are hospitalized are few, depending on the symptoms experienced. Hosts of COVID-19 are humans, especially vulnerable groups who have low immunity. The physical environment of the COVID-19 virus is like poor environmental sanitation, the biological environment, for example, population density, virus virulence, the socio-cultural environment such as behavior, economic, and politics (Susanti, 2022).

The increase in the generation of infectious waste during the pandemic occurred in all countries (Sarkodie & Owusu, 2021a), including Indonesia, with a scale of 12,740 tons of medical waste after the first infection case was announced (Mihai, 2020). It also happened in Padang City, where the number of treatments correlated closely with the amount of infectious waste 100 – 200% before the COVID-19 pandemic in this dynamic system simulation. The increase in the generation of infectious waste during the COVID-19 pandemic was caused by all the waste generated from attributes used in handling COVID-19, such as personal protective equipment, face masks, gloves, etc., as well as food waste originating from the COVID-19 inpatient room (Aldaco et al., 2020; Sangkham, 2020). If this infectious waste is not controlled, then the presence can cause transmission of deadly diseases, especially COVID-19, because waste acts as a vector for the corona virus disease, which lasts up to 7 days in COVID-19 waste such as masks (Ilyas et al., 2020; Nzediegwu & Chang, 2020).

To control infectious waste during the COVID-19 pandemic, it is necessary to handle it from upstream through compliance with health protocols, PSBB policies issued by the government, and mandatory vaccinations. With optimal control of the generation of infectious waste during the COVID-19 pandemic, it will directly reduce the costs and activities of processing the infectious waste itself. In Padang City, the treatment is managed by a third party (transporter/carrier) to be destroyed on the island of Java. During the transportation period, infectious waste potentially spreads the virus, because third parties do not have complete control over the time factor while traveling.

For this reason, it is necessary to have models and policy recommendations for the sustainability of hospital infectious waste control in Padang City based on the dynamic system during the COVID-19 pandemic (Ding et al., 2016), namely by optimizing vaccinations, health protocols, and PSBB. With this model and policy recommendations, infectious waste can be reduced and controlled. The COVID-19 pandemic has become a global crisis that can disrupt the achievement of the Sustainable Development Goals (TPB/SDGs). The pandemic created tension on a global level. On the one hand, it causes countries to close borders, limit the movement of people and goods, and make authoritarian policies, but on the other hand, global cooperation is needed to tackle a pandemic that is inherently global (Shulla et al., 2021). The pandemic poses a challenge to the global community to work collaboratively with many ways being explored and stakeholders involved to find solutions due to commonalities and interrelated goals (van Zanten & van Tulder, 2020).

Achieving the Sustainable Development Goals will take longer. For developing countries, it will be difficult to create policies aligned with the Sustainable Development Goals in the wake of the COVID-19 pandemic and grow towards the seventeen Sustainable Development Goals (Nundy et al., 2021). The environmental pillar as the third of the four Sustainable Development Goals, precisely on the goals of (6) Clean Water and Adequate Sanitation, (11) Sustainable Cities and Settlements; (12) Responsible Consumption and Production; (13) Climate Change Handling; (14) Ocean Ecosystems; and (15) Mainland Ecosystems. This research produces models and policy recommendations for controlling hospital infectious waste in Padang City based on system dynamics during the COVID-19 pandemic, so it can be concluded that this research directly contributes to the goals in the environmental pillar.

Conclusion

Policy recommendations for controlling infectious waste in Padang City hospitals based on the COVID-19 Pandemic case dynamic system are optimizing vaccination scenarios, optimizing health protocol scenarios, and optimizing PSBB scenarios that can suppress and reduce the positive number of COVID-19, the number of treatments and reduce the amount of infectious waste generation in the Padang City hospital.

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