Projection of incinerators for medical waste processing during a pandemic: a case study of COVID-19 in Jakarta Province

M H Aryantie¹*, T Widodo², R Wahyuni¹, B Purwanto¹, and M Y Hidayat¹

¹ Center for Standardization of Environmental Quality Instruments, Gedung 210 PUSPIPTEK, Serpong, Banten, 15314, Indonesia
² Population and Family Planning Board of West Sumatra, Indonesia

*E-mail: melania.hanny@gmail.com

Abstract. Medical waste management due to the COVID-19 pandemic is important and urgent. An approach is needed to assess the weight of medical waste and to design appropriate waste management. The research was conducted in 2020 when the pandemic was still ongoing and had not yet reached the peak of the outbreak. Thus, the analysis was built based on assumptions and available data. The research was quantitative. Data were collected digitally (by big data retrieval and web survey) on the COVID-19 referral hospitals in Jakarta Province. The results showed that before the pandemic the weight of inpatients' medical waste was 1.57 kg/bed/day, while for COVID-19 inpatients was 1.84 kg/bed/day. The last number was processed with a limited projection of Jakarta population in 2020, then tested using two scenarios. First scenario was a pandemic condition without treatment. Second scenario was a pandemic condition plus vaccinations on D11. First scenario resulted that on D75, almost all residents of Jakarta would be infected with the SARS-COV2 virus and the maximum capacity of hospital incinerators in Jakarta was reached on D11. Second scenario resulted that the plague rate is resolved so that it does not infect all residents of Jakarta, but the capacity of hospital incinerators in Jakarta is still not adequate (limit on D11). Research has implications for environmental management budget planning in dealing with infectious disease outbreaks. The research recommendation is to calculate the weight of COVID-19 medical waste according to current conditions, which includes parameters such as the maximum hospital occupancy rate and the availability of large-scale incinerators belong to third-party.

1. Introduction

Personal protective equipment used by health workers and all medical equipment that has been directly affected by COVID-19 patients are classified as medical hazardous and toxic (B3/bahan berbahaya dan beracun) waste according to Indonesian regulations. This waste is categorized as infectious/easily transmitted between humans. In other words, this medical B3 waste endangers human health and potential to pollute the environment [1]. Medical waste in solid form is generated from treatment room activities (inpatient health centers, general polyclinics, dental polyclinics, maternal and child polyclinics, laboratories and pharmacies). Liquid waste comes from laboratories which may contain microorganisms, toxic chemicals, and radioactivity [2]. Medical B3 waste can come from expired B3, spilled B3, B3 that does not meet product specifications to be disposed of, used B3 packaging, and B3 waste from specific sources [3].

A treatment for infectious B3 waste is incineration, the process of destroying waste in an organized high-temperature device (incinerator) to reduce solid waste turn into ashes, and to neutralize and to solidify the
burnt ash [4, 5]. Incinerators can reduce the mass of waste by 70% and reduce volume up to 90% [5] and kill bacteria, viruses, and toxic chemicals [6, 7]. Tsai [8] also supports the chain of SARS-COV2 virus spread breaking through the use of incinerators. Incineration also has problems, so a vigilant approach is needed with strict supervision [9], because the failure to handle infectious/medical waste is generally caused by human error [10]. There is a tendency that small-scale incineration facilities are more hazardous than large-scale incineration facilities. It is suspected that the optimal temperature is not achieved and the instability of the combustion process so that the waste does not burn completely [11, 12]. The other three processing methods are autoclave, microwave, and radio frequency irradiation. However, they are prohibited by Indonesian law for cytotoxic waste and infectious pathological waste treatment. All of them are not included in the scope of the study.

The research began when the COVID-19 pandemic was just starting. This condition is one of the factors causing COVID-19 inpatients medical waste weight is not much different from general inpatients medical waste weight [8]. Nevertheless, research results showing the weight of infectious medical waste increase during the COVID-19 outbreak [8, 13, 14] and its impact on waste management facilities are not projected. This becomes important for regional governments to predict the excess limits of their facilities and to plan further supervision options. Through this study, the number of COVID-19 inpatients and their waste generation is projected with a population limit of DKI Jakarta. Then the results of the projection are calculated by the incinerators availability and the excess waste load is multiplied by the budget requirement. The final result shows the budget needs that must be prepared by the government in managing medical waste during the pandemic.

This research is a combination of environmental management, health, and demographics. The study results are important to determine the prediction of the number of inpatients and their waste generation in two conditions (control and by intervention). Calculations prove that through intervention (vaccination), the rate of inpatients increase slowed down so that it did not reach the limit (Jakarta population in 2020). However, the waste production during both conditions were almost the same, so supplementary incinerator facilities were needed in addition to the 6 hospitals’ incinerators in Jakarta. This research helps the government to prevent environmental disaster by the rise of B3 waste volume caused by force majeure in the future.

The research objective is to describe the need for B3 waste processing facilities in the form of incinerators in dealing with pandemic conditions through 2 scenarios (without and with intervention/vaccination). This manuscript presents four important things for Jakarta case study, i.e. 1) the daily production of COVID-19 patients waste when the pandemic began, 2) the projection of the number of COVID-19 patients increase, 3) the projection of the medical B3 waste weight increase from referral hospitals, and 4) budget needs for additional incinerators provision during the pandemic. Given that the research was conducted early in the COVID-19 pandemic, this activity does not take into account the emergence of mutated virus variants.

2. Method
This was descriptive research [15], namely observing and describing changes in the number of COVID-19 inpatients, medical B3 waste generated by COVID-19 referral hospitals in DKI Jakarta Province and the impact on regional government budgeting. Data was collected online considering the restrictions on activities by the government in the initial conditions of the pandemic. The list of COVID-19 referral hospitals was obtained from the Jakarta Provincial Health Office. The questionnaire was sent via web survey.

From the questionnaire, data were obtained to calculate the daily weight of medical waste from inpatients with the equation (1) [16] as follows:

\[ Th = TLM \times TT \times P \] (1)
\[ Th = \text{total daily medical waste (kg)} \]
\[ TLM = \text{average daily medical waste production (kg/bed)} \]
\[ TT = \text{total number of beds (bed)} \]
\[ P = \text{average daily occupancy rate (%)} \]

From the data received, \( Th \) is obtained for general inpatients and for COVID-19 inpatients.

The projection using limit means marking the population limit for Jakarta in 2020 based on the Central Bureau of Statistics data (SUPAS BPS/Survei Penduduk Antar Sensus, Badan Pusat Statistik, 2015) which is 10.57 million people. This means that the projected range of the number of COVID-19 sufferers based on the rate of spread does not exceed the current population. By using the same assumption (ceteris paribus), the rate of patients’ growth in Jakarta in one year is formulated using a linear projection (equation (2)) as follows:

\[ Pt = \lim_{t \to 10.57\text{million}} Po(1 + r) \]  

\[ Pt = \text{Number of people with COVID-19 in one year (365/10 days = 36.5); “10 days” calculating based on BPS projection with constant increase} \]
\[ Po = \text{Number of COVID-19 inpatients until August 2020 who were treated by hospitals in Jakarta} \]

The projection of additional incinerators is based on the generated infectious waste divided by the current capacity of the hospital's incinerators. In simple terms it can be formulated in equation (3) as follows:

\[ \text{Incinerators needs (unit)} = \frac{\text{Generated waste projection}}{\text{Incinerators capacity}} \]  

The total cost of incinerators procurement can be formulated in equation (4) as follows:

\[ \text{Incinerators procurement cost} = \text{Machine requirement x the price of 1 unit incinerator} \]

3. Results and discussion
3.1. Average daily medical waste production of general inpatients and COVID-19 inpatients

Data was collected from 16 COVID-19 referral hospitals in Jakarta area. The respondents represented 4 types of hospitals (type A to type D). Table 1 shows the condition of daily medical waste from general inpatients during 2019. From this data, the average daily medical waste production (TLM) of general inpatients was 1.57 kg/bed/day. This result is slightly different from other studies at 1.58 kg/bed/day [13].
Table 1. Daily medical waste production of general inpatients in 2019.

| Hospital code | Hospital type | Total number of beds (TT) | Average daily occupancy rate (P) | Average daily medical waste production (TLM) | Total daily medical waste (Th) |
|---------------|---------------|---------------------------|----------------------------------|---------------------------------------------|------------------------------|
| RC18          | B             | 145                       | -                                | 0.90                                        | 0.00 0.00                    |
| RC66          | C             | 97                        | 60.00                            | 3.00                                        | 17,460.00 17.46             |
| RC24          | B             | 144                       | 38.00                            | 3.29                                        | 18,000.00 18.00             |
| RC36          | B             | 253                       | 78.00                            | 2.00                                        | 39,468.00 39.47             |
| RC10          | B             | 311                       | 31.71                            | 1.50                                        | 14,792.72 14.79             |
| RC57          | B             | 374                       | 65.70                            | 0.11                                        | 2,700.00 2.70               |
| RC47          | C             | 100                       | 68.36                            | 1.10                                        | 7,519.60 7.52               |
| RC63          | A             | 207                       | 60.76                            | 0.96                                        | 12,049.07 12.05             |
| RC3           | A             | 420                       | 80.00                            | 1.18                                        | 39,648.00 39.65             |
| RC55          | A             | 595                       | 61.09                            | 1.43                                        | 51,978.43 51.98             |
| RC51          | B             | 200                       | 61.81                            | 5.00                                        | 61,810.00 61.81             |
| RC44          | B             | 145                       | 42.93                            | 1.50                                        | 9,337.28 9.34               |
| RC11          | B             | 235                       | 57.00                            | 1.19                                        | 16,000.00 16.00             |
| RC26          | B             | 113                       | 40.64                            | 0.32                                        | 1,471.00 1.47               |
| RC50          | D             | 44                        | 28.20                            | 0.71                                        | 880.97 0.88                 |
| RC62          | B             | 206                       | 55.00                            | 1.00                                        | 11,330.00 11.33             |

1.57 kg/bed/day

Data on COVID-19 infectious waste from hospitals in Jakarta began to be generated on March 22, 2020 (covid19.go.id). Table 2 shows the condition of daily medical waste from inpatients with COVID-19 until August 2020. From this data, the TLM figure for inpatients with COVID-19 is 1.84 kg/TT/day. This value is not much different from the general inpatients waste weight because the study was carried out when the epidemic was just started, according to the results of Tsai's analysis [8].

Table 2. Daily medical waste of COVID-19 inpatients in 2020.

| Hospital code | Hospital type | Total number of beds (TT) | Average daily occupancy rate (P) | Average daily medical waste production (TLM) | Total daily medical waste (Th) |
|---------------|---------------|---------------------------|----------------------------------|---------------------------------------------|------------------------------|
| RC18          | B             | 19                        | 70.18                            | 1                                          | 1,333.42 1.33               |
| RC66          | C             | 29                        | 60.00                            | 5                                          | 8,700.00 8.70               |
| RC24          | B             | 14                        | 37.00                            | 1.93                                        | 999.74 1.00                 |
| RC36          | B             | 48                        | 9.00                             | 1                                          | 432.00 0.43                 |
| RC10          | B             | 56                        | 27.34                            | 2.3                                         | 3,521.39 3.52               |
| RC57          | B             | 73                        | 83.50                            | 1.3                                         | 7,924.15 7.92               |
| RC47          | C             | 23                        | 22.73                            | 1.5                                         | 784.19 0.78                 |
| RC63          | A             | 29                        | 50.00                            | 1.2                                         | 1,740.00 1.74               |
| Hospital code | Hospital type | Total number of beds (TT) | Average daily occupancy rate (P) | Average daily medical waste production (TLM) | Total daily medical waste (Th) |
|---------------|---------------|--------------------------|---------------------------------|---------------------------------------------|-------------------------------|
| RC3           | A             | 156                      | 80.00                           | 1.18                                        | 14,726.40 (14.73)            |
| RC55          | A             | 189                      | 66.64                           | 1.97                                        | 24,812.07 (24.81)            |
| RC51          | B             | 18                       | 46.26                           | 0.96                                        | 799.37 (0.80)                |
| RC44          | B             | 37                       | 90.00                           | 2                                           | 6,660.00 (6.66)              |
| RC11          | B             | 101                      | 100.00                          | 1.48                                        | 14,948.00 (14.95)            |
| RC26          | B             | 16                       | 43.75                           | 2.9                                         | 2,030.00 (2.03)              |
| RC50          | D             | 13                       | 41.67                           | 2.75                                        | 1,489.70 (1.49)              |
| RC62          | B             | 40                       | 90.00                           | 1                                           | 3,600.00 (3.60)              |

1.84 kg/bed/day

The average increase of COVID-19 patients’ number is calculated from the daily mean positivity rate for DKI Jakarta cases (corona.jakarta.go.id) in October 2020. From this data, it was known that the number of patients being treated increased by 10.3% per day.

From those calculation, the average medical waste production for COVID-19 patients (kg/bed/day), the average increase in the number of COVID-19 patients (%/day), the number of incinerators (unit) and the capacity of the incinerator (kg/hour) are shown in Table 3. The availability of incinerators is assumed to rely solely on hospitals in Jakarta, which is as many as six (6) units (Jakarta Provincial Environmental Service, 2020).

**Table 3. COVID-19 conditions faced by the DKI Jakarta referral hospitals in 2020.**

| Number of COVID-19 inpatients (people) | Average daily medical waste production from COVID-19 inpatients (kg/bed/day) | Total waste (kg) | Average increase in the number of COVID-19 patients (% per day) | Number of hospital incinerators in Jakarta (unit) | Incinerator capacity per unit (kg/hour) |
|----------------------------------------|------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------|-----------------------------------------------|--------------------------------------|
| 208                                    |                                                                              | 382.72           |                                                                 |                                              |                                      |
| 358                                    |                                                                              | 658.72           |                                                                 |                                              |                                      |
| 129                                    |                                                                              | 237.36           |                                                                 |                                              |                                      |
| 168                                    |                                                                              | 309.12           |                                                                 |                                              |                                      |
| 997                                    |                                                                              | 1834.48          |                                                                 |                                              |                                      |
| 454                                    |                                                                              | 835.36           |                                                                 |                                              |                                      |
| 124                                    |                                                                              | 228.16           |                                                                 |                                              |                                      |
| 413                                    | 1.84                                                                         | 759.92           | 10.30                                                           |                                              |                                      |
| 1189                                   |                                                                              | 2187.76          |                                                                 | 6                                             | 100                                  |
| 1683                                   |                                                                              | 3096.72          |                                                                 |                                              |                                      |
| 118                                    |                                                                              | 217.12           |                                                                 |                                              |                                      |
| 184                                    |                                                                              | 338.56           |                                                                 |                                              |                                      |
| 630                                    |                                                                              | 1159.2           |                                                                 |                                              |                                      |
| 170                                    |                                                                              | 312.8            |                                                                 |                                              |                                      |
3.2. Projected number of COVID-19 patients and their waste

A limited linear projection means marking the limit on the population of Jakarta at the time of the study (in 2020) based on the Central Bureau of Statistics data (SUPAS BPS, 2015) of around 10.57 million people. This means that the projected range of the number of COVID-19 sufferers based on the rate of spread does not exceed that population. Using a linear projection formula with Pt = 365 days/10 days = 36.5 and Po = 7253 COVID-19 patients, the number of COVID-19 patients and their waste is illustrated in Table 4.

| Day-n (x10) | Total patient projection (people) | Trend of additional COVID-19 patients per 10 days | Medical waste projection (kg) |
|-------------|----------------------------------|-----------------------------------------------|-------------------------------|
| 1           | 7,253                            | -                                             | 13,346                        |
| 2           | 8,000                            | 747                                           | 14,720                        |
| 3           | 8,824                            | 824                                           | 16,236                        |
| 4           | 9,733                            | 909                                           | 17,909                        |
| 5           | 10,735                           | 1,002                                         | 19,753                        |
| 6           | 11,841                           | 1,106                                         | 21,788                        |
| 7           | 13,061                           | 1,220                                         | 24,032                        |
| 8           | 14,406                           | 1,345                                         | 26,507                        |
| 9           | 15,890                           | 1,484                                         | 29,237                        |
| 10          | 17,527                           | 1,637                                         | 32,249                        |
| 11          | 19,332                           | 1,805                                         | 35,571                        |
| 12          | 21,323                           | 1,991                                         | 39,234                        |
| 13          | 23,519                           | 2,196                                         | 43,275                        |
| 14          | 25,942                           | 2,422                                         | 47,733                        |
| 15          | 28,614                           | 2,672                                         | 52,649                        |
| 16          | 31,561                           | 2,947                                         | 58,072                        |
| 17          | 34,812                           | 3,251                                         | 64,054                        |
| 18          | 38,397                           | 3,586                                         | 70,651                        |
| 19          | 42,352                           | 3,955                                         | 77,928                        |
| 20          | 46,715                           | 4,362                                         | 85,955                        |
| 21          | 51,526                           | 4,812                                         | 94,808                        |
| 22          | 56,833                           | 5,307                                         | 104,573                       |
| 23          | 62,687                           | 5,854                                         | 115,344                       |
| 24          | 69,144                           | 6,457                                         | 127,225                       |
| 25          | 76,266                           | 7,122                                         | 140,329                       |
| 26          | 84,121                           | 7,855                                         | 154,783                       |
| Day-n (x10) | Total patient projection (people) | Trend of additional COVID-19 patients per 10 days | Medical waste projection (kg) |
|------------|---------------------------------|-----------------------------------------------|-----------------------------|
| 27         | 92,786                          | 8,664                                         | 170,726                     |
| 28         | 102,343                         | 9,557                                         | 188,310                     |
| 29         | 112,884                         | 10,541                                        | 207,706                     |
| 30         | 124,511                         | 11,627                                        | 229,100                     |
| 31         | 137,336                         | 12,825                                        | 252,697                     |
| 32         | 151,481                         | 14,146                                        | 278,725                     |
| 33         | 167,084                         | 15,603                                        | 307,434                     |
| 34         | 184,293                         | 17,210                                        | 339,100                     |
| 35         | 203,276                         | 18,982                                        | 374,027                     |
| 36         | 224,213                         | 20,937                                        | 412,552                     |
| 37         | 247,307                         | 23,094                                        | 455,045                     |
| 38         | 272,779                         | 25,473                                        | 501,914                     |
| 39         | 300,876                         | 28,096                                        | 553,611                     |
| 40         | 331,866                         | 30,990                                        | 610,633                     |
| 41         | 366,048                         | 34,182                                        | 673,529                     |
| 42         | 403,751                         | 37,703                                        | 742,902                     |
| 43         | 445,337                         | 41,586                                        | 819,421                     |
| 44         | 491,207                         | 45,870                                        | 903,821                     |
| 45         | 541,802                         | 50,594                                        | 996,915                     |
| 46         | 597,607                         | 55,806                                        | 1,099,597                   |
| 47         | 659,161                         | 61,554                                        | 1,212,856                   |
| 48         | 727,054                         | 67,894                                        | 1,337,780                   |
| 49         | 801,941                         | 74,887                                        | 1,475,571                   |
| 50         | 884,541                         | 82,600                                        | 1,627,555                   |
| 51         | 975,648                         | 91,108                                        | 1,795,193                   |
| 52         | 1,076,140                        | 100,492                                       | 1,980,098                   |
| 53         | 1,186,983                        | 110,842                                       | 2,184,048                   |
| 54         | 1,309,242                        | 122,259                                       | 2,409,005                   |
| 55         | 1,444,094                        | 134,852                                       | 2,657,132                   |
| 56         | 1,592,835                        | 148,742                                       | 2,930,817                   |
| 57         | 1,756,897                        | 164,062                                       | 3,232,691                   |
| 58         | 1,937,858                        | 180,960                                       | 3,565,658                   |
| 59         | 2,137,457                        | 199,599                                       | 3,932,921                   |
| 60         | 2,357,615                        | 220,158                                       | 4,338,012                   |
| 61         | 2,600,449                        | 242,834                                       | 4,784,827                   |
| 62         | 2,868,296                        | 267,846                                       | 5,277,664                   |
| 63         | 3,163,730                        | 295,434                                       | 5,821,264                   |
| 64         | 3,489,594                        | 325,864                                       | 6,420,854                   |
| 65         | 3,849,023                        | 359,428                                       | 7,082,202                   |
| 66         | 4,245,472                        | 396,449                                       | 7,811,669                   |
| 67         | 4,682,756                        | 437,284                                       | 8,616,270                   |
| 68         | 5,165,080                        | 482,324                                       | 9,503,746                   |
| 69         | 5,697,083                        | 532,003                                       | 10,482,632                  |
| 70         | 6,283,882                        | 586,800                                       | 11,562,343                  |
| 71         | 6,931,122                        | 647,240                                       | 12,753,265                  |
| 72         | 7,645,028                        | 713,906                                       | 14,066,851                  |
The first scenario is that the transmission of the virus occurs naturally, without any intervention to control the pandemic, and there is no virus mutation. Based on a linear projection with a limit of 10.57 million inhabitants of DKI Jakarta (benchmark), it is predicted that in the first scenario the entire population will be infected with the SARS-COV2 virus on D75 (Table 4, Figure 1). D75 means at the 75th time per 10 days. The projection results that almost all residents of DKI Jakarta can be infected on the 750th day (September 2022) if mechanism is not carried out on the corona virus spread.

| Day-n (x10) | Total patient projection (people) | Trend of additional COVID-19 patients per 10 days | Medical waste projection (kg) |
|-------------|----------------------------------|-----------------------------------------------|-------------------------------|
| 73          | 8,432,466                        | 787,438                                      | 15,515,737                   |
| 74          | 9,301,099                        | 868,544                                      | 17,113,857                   |
| 75          | 10,259,013                       | 958,004                                      | 18,876,585                   |
| 76          | 11,315,692                       | 1,056,678                                    | 20,820,873                   |
| 77          | 12,481,208                       | 1,165,516                                    | 22,965,423                   |
| 78          | 13,766,772                       | 1,285,564                                    | 25,330,861                   |
| 79          | 15,184,750                       | 1,417,978                                    | 27,939,940                   |
| 80          | 16,748,779                       | 1,564,029                                    | 30,817,754                   |

Figure 1. Projected number of COVID-19 patients in scenario 1.

Based on the results of the projected weight of medical waste (Figure 2), D11 is the maximum threshold for 6 hospital incinerators in Jakarta to burn all medical waste. In other words, on the 110th day (December 2020), additional incinerators were needed. The extra incinerators are carried out if the burning capacity of each incinerator has exceeded 600 kg/day (capacity of 100 kg/hour with an effective combustion time of 6
hours/day). For more details, the projected weight of medical waste and incinerators capacity (benchmark) in Jakarta can be seen in Figure 2.

![Figure 2. Projected weight of COVID-19 patients’ medical waste in scenario 1.](image)

The second scenario is that the government intervenes to control the pandemic through vaccination. It does not take into account incidental events such as the increase after the long holidays and the emergence of new virus variants that are more aggressive. The starting point for vaccination is D11. The reference for scenario 2 is that the increase in the number of patients is constant because it is considered part of the process of getting vaccinated where the average daily number of cases is ten days. The basis for determining the projection for ten days refers to the Central Statistics Agency (BPS) standard which is carried out for 10 projection periods. The longer the projection time, the greater the probability. The reason for the population census every 10 years by BPS is to determine the starting point for the next 10 period’s projection. Thus, for the initial case on the first day, the calculation of the number of COVID-19 patients on the first to the tenth day in a row is as follows: 747, 824, 909, 1,002, 1,106, 1,220, 1,345, 1,484, 1,637 patients (Table 5). When averaged, the increase in COVID-19 sufferers is 1,142 people/day and this figure is used for the next projection. Starting on D11 (110th day or December 2020), the addition of COVID-19 patients was stable at 1,142 people/day (Table 5).

### Table 5. Projected number of COVID-19 patients and their waste in scenario 2.

| Day-n (x10) | Total patient projection (people) | Trend of additional COVID-19 patients per 10 days | Medical waste projection (kg) |
|-------------|---------------------------------|-----------------------------------------------|-----------------------------|
| 1           | 7,253                           | -                                             | 13346                       |
| 2           | 8,000                           | 747                                           | 14,720                      |
| 3           | 8,824                           | 824                                           | 16,236                      |
| Day-n (x10) | Total patient projection (people) | Trend of additional COVID-19 patients per 10 days | Medical waste projection (kg) |
|------------|----------------------------------|-----------------------------------------------|-----------------------------|
| 4          | 9,733                            | 909                                           | 17,909                      |
| 5          | 10,735                           | 1,002                                         | 19,753                      |
| 6          | 11,841                           | 1,106                                         | 21,788                      |
| 7          | 13,061                           | 1,220                                         | 24,032                      |
| 8          | 14,406                           | 1,345                                         | 26,507                      |
| 9          | 15,890                           | 1,484                                         | 29,237                      |
| 10         | 17,527                           | 1,637                                         | 32,249                      |
| 11         | 18,668                           | 1,142                                         | 34,349                      |
| 12         | 19,810                           | 1,142                                         | 36,450                      |
| 13         | 20,951                           | 1,142                                         | 38,550                      |
| 14         | 22,093                           | 1,142                                         | 40,650                      |
| 15         | 23,234                           | 1,142                                         | 42,751                      |
| 16         | 24,376                           | 1,142                                         | 44,851                      |
| 17         | 25,517                           | 1,142                                         | 46,952                      |
| 18         | 26,659                           | 1,142                                         | 49,052                      |
| 19         | 27,800                           | 1,142                                         | 51,152                      |
| 20         | 28,942                           | 1,142                                         | 53,253                      |
| 21         | 30,083                           | 1,142                                         | 55,353                      |
| 22         | 31,225                           | 1,142                                         | 57,453                      |
| 23         | 32,366                           | 1,142                                         | 59,554                      |
| 24         | 33,508                           | 1,142                                         | 61,654                      |
| 25         | 34,649                           | 1,142                                         | 63,755                      |
| 26         | 35,791                           | 1,142                                         | 65,855                      |
| 27         | 36,932                           | 1,142                                         | 67,955                      |
| 28         | 38,074                           | 1,142                                         | 70,056                      |
| 29         | 39,215                           | 1,142                                         | 72,156                      |
| 30         | 40,357                           | 1,142                                         | 74,256                      |
| 31         | 41,498                           | 1,142                                         | 76,357                      |
| 32         | 42,640                           | 1,142                                         | 78,457                      |
| 33         | 43,781                           | 1,142                                         | 80,558                      |
| 34         | 44,923                           | 1,142                                         | 82,658                      |
| 35         | 46,064                           | 1,142                                         | 84,758                      |
| 36         | 47,206                           | 1,142                                         | 86,859                      |
| 37         | 48,347                           | 1,142                                         | 88,959                      |
| 38         | 49,489                           | 1,142                                         | 91,059                      |
| 39         | 50,630                           | 1,142                                         | 93,160                      |
| 40         | 51,772                           | 1,142                                         | 95,260                      |
| 41         | 52,913                           | 1,142                                         | 97,361                      |
| 42         | 54,055                           | 1,142                                         | 99,461                      |
| 43         | 55,196                           | 1,142                                         | 101,561                     |
| 44         | 56,338                           | 1,142                                         | 103,662                     |
| 45         | 57,479                           | 1,142                                         | 105,762                     |
| 46         | 58,621                           | 1,142                                         | 107,862                     |
| 47         | 59,762                           | 1,142                                         | 109,963                     |
| 48         | 60,904                           | 1,142                                         | 112,063                     |
| 49         | 62,045                           | 1,142                                         | 114,164                     |
| Day-n (x10) | Total patient projection (people) | Trend of additional COVID-19 patients per 10 days | Medical waste projection (kg) |
|------------|---------------------------------|-----------------------------------------------|-----------------------------|
| 50         | 63,187                          | 1,142                                         | 116,264                     |
| 51         | 64,328                          | 1,142                                         | 118,364                     |
| 52         | 65,470                          | 1,142                                         | 120,465                     |
| 53         | 66,611                          | 1,142                                         | 122,565                     |
| 54         | 67,753                          | 1,142                                         | 124,666                     |
| 55         | 68,895                          | 1,142                                         | 126,766                     |
| 56         | 70,036                          | 1,142                                         | 128,866                     |
| 57         | 71,178                          | 1,142                                         | 130,967                     |
| 58         | 72,319                          | 1,142                                         | 133,067                     |
| 59         | 73,461                          | 1,142                                         | 135,167                     |
| 60         | 74,602                          | 1,142                                         | 137,268                     |
| 61         | 75,744                          | 1,142                                         | 139,368                     |
| 62         | 76,885                          | 1,142                                         | 141,469                     |
| 63         | 78,027                          | 1,142                                         | 143,569                     |
| 64         | 79,168                          | 1,142                                         | 145,669                     |
| 65         | 80,310                          | 1,142                                         | 147,770                     |
| 66         | 81,451                          | 1,142                                         | 149,870                     |
| 67         | 82,593                          | 1,142                                         | 151,970                     |
| 68         | 83,734                          | 1,142                                         | 154,071                     |
| 69         | 84,876                          | 1,142                                         | 156,171                     |
| 70         | 86,017                          | 1,142                                         | 158,272                     |
| 71         | 87,159                          | 1,142                                         | 160,372                     |
| 72         | 88,300                          | 1,142                                         | 162,472                     |
| 73         | 89,442                          | 1,142                                         | 164,573                     |
| 74         | 90,583                          | 1,142                                         | 166,673                     |
| 75         | 91,725                          | 1,142                                         | 168,773                     |
| 76         | 92,866                          | 1,142                                         | 170,874                     |
| 77         | 94,008                          | 1,142                                         | 172,974                     |
| 78         | 95,149                          | 1,142                                         | 175,075                     |
| 79         | 96,291                          | 1,142                                         | 177,175                     |
| 80         | 97,432                          | 1,142                                         | 179,275                     |

With vaccination, it is assumed that the rate of COVID-19 patients’ growth can be controlled so that the population of DKI Jakarta will not be entirely infected with the SARS-COV2 virus (Table 5, Figure 3). It can be seen that until D80, the number of patients did not reach the limit of 10.57 million people (benchmark).
However, although the number of infected patients can be controlled, the production of medical waste continues to increase according to a linear projection. In Figure 4 it can be seen that on D11 (11th day or December 2020), medical waste has reached the maximum processing limit with 6 incinerators belong to hospitals in Jakarta. From this it can be stated that starting on January 2021, the government of Jakarta must provide additional incinerators for processing the waste of COVID-19 patients.
3.3. **Budget planning on medical waste treatment**

From the questionnaire, the hospital incinerator capacity is known to be 50-100 kg/hour. The government assumes the capacity of the hospital incinerator is 200 kg/hour [16]. Khabibimuna et al. [17] stated that the incinerator processing capacity in Jakarta hospitals up to 250 kg/hour. The effective burning time is 6 hours/day based on the operator's working hours (1 shift/day) and the time lag for filling the waste into the combustion engine.

The lowest market price for an incinerator with 100 kg/hour capacity is IDR 993 million, while the capacity of 200-250 kg/hour is IDR 1.5 billion. Based on those rates in 2020, the total cost of procuring incinerators when Jakarta citizens is almost entirely infected with the SARS-COV2 virus simultaneously (Table 4, D75 scenario 1) can be formulated in Table 6 as follows:

**Table 6. Medical waste treatment budget during COVID-19 outbreak.**

| Waste weight (kg) | Incinerator needs (unit) | Procurement fee (IDR) |
|-------------------|--------------------------|-----------------------|
|                   | 100 kg/hour              | 250 kg/hour           |
|                   | 100 kg/hour              | 250 kg/hour           |
| 18,876,585        | 31,461                   | 12,584                |
| 31.24 trillion    | 18.88 trillion           |

To avoid huge procurement costs, Jakarta government has an option to hire waste processing company that has a capacity of up to 12 tons/day/company [18]. Referring to Zhang et al., WHO, and Mayang et al. that the use of incinerators is recommended on a large scale for efficiency and reducing the impact of environmental pollution [11, 12, 18]. Das et al. [14] suggested mobile incinerator, cement kilns, and other industrial furnaces without budget analysis to consider.
4. Conclusion

Based on COVID-19 case in Jakarta, the weight of COVID-19 inpatients waste was 1.84 kg/bed/day. It was generated when the outbreak just began. It is slightly different from the common inpatients’ waste, 1.57 kg/bed/day. In the scenario 1 without intervention in handling the plague, almost all of Jakarta citizens will be completely infected on D75 (September 2022). In the scenario 2 with intervention/vaccination, until D80 the citizens will not completely infected.

Both scenarios show that on D11 (December 2020), the capacity of 6 incinerators belong to hospitals in Jakarta has been exceeded. The local government may choose the option of procuring extra incinerators or using the waste processing company service. The budget for the additional incinerators during the pandemic is illustrated by the results of scenario I (D75) of IDR 31.24 trillion (US$ 2.2 billion) for incinerators with the capacity of 100 kg/hour/unit and IDR 18.88 trillion (US$ 1.3 billion) for incinerators with the capacity of 250 kg/hour/unit. These are the suitable sizes for hospital level.

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