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# SCENARIOS TACKLING MUNICIPAL SOLID WASTE (MSW) FLOW INTO LANDFILL BASED ON MFA-STAN INTEGRATIVE METHOD TOWARDS BUILDING SUSTAINABLE CITY IN INDONESIA

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**ABSTRACT**

Municipal solid waste (MSW) generation increased significantly each year impacted to the increasingly critical landfill area. This study aims to determine the critical MSW flow in the landfill to be repaired and developed for sustainable waste infrastructure, to design the best scenario tackling the MSW flow into the landfill based on the potential to recycle, recovery materials (compost) and recovery energy/fuel from MSW (RDF/Refuse Derived Fuel). The method is about direct measurement at the landfill for MSW composition according to SNI 19-3964-1994 and physical characteristics; testing the samples in the laboratory for chemical characteristics; empirical calorific value and doing survey to scavengers. Then make modeling scenarios to tackle MSW by using MFA-STAN (Material Flow Analysis-short for Substance Flow Analysis) integrative method for each year over a period of five years. MSW critical flow in the landfill to be repaired and developed for sustainable MSW infrastructure contained in the composition of organics (65,75%) and plastics (11,937%). Based on laboratory tests and surveys, waste processing technology potentially applicated by composting (58,906%), recycling (25,417%) and RDF (27,619%). Scenario 3 is appropriate scenario to reduce MSW to be dumped (about more than 50%) also to increase the lifespan of serviceability landfill.

**Keywords:** composting, landfill, MFA-STAN , recycling, RDF.

## INTRODUCTION

Landfill is no longer only expected to be a Municipal Solid Waste (MSW) landfill/final disposal of garbage but it becomes final municipal waste processing place [18]. Final waste processing place (in Indonesia named TPA) Cipayung is the only landfill in Depok used since 1984, located in the Village Cipayung, District Pancoran Mas (Indonesia). Waste management system in Cipayung landfill is open dumping method (1984-2002) and after that-up to now applying controlled landfill method. Cipayung landfill area is 6,1 ha (1984-2002); 9,1 ha (2002-2007) and the last addition of area to 11,2 ha (2008-current). Cipayung landfill capacity is 1.500.00 m3. The amount of waste that goes to Cipayung landfill 800-1200 m3/day, or an average of 1000 m3/day. Cipayung landfill area has reached a critical period as the increasing of waste, which had the rate of volume increasing 10% annually since 2006-2009 [7]. Inadequate understanding of the material flow becomes a limiting factor to reach sustainable development [22].

As cited from [15], systems analysis techniques have been applied to handle municipal waste flow through an integrative methodology in recent decades. For example, MFA (Material Flow Analysis) is an analysis of the material flow which has a systematic assessment of the flow and stock of materials in a system defined in space and time. Softwares were developed in MFA, the Sfinx (van der Voet, 1995), FLUX (Huijbregts, 2000), STAN (TU Vienna, 2009), DYNFLOW (Elshkak, 2000), Gabi (PE International, 2006) and Umberto (IFU, 2006).
MFA was formed through the mass balance model STAN (short for substance flow analysis) referred to the standard ÖNorm Austria 2096 [4]. It has been applied to various waste application fields, such as home composting [1], various scenarios of material flow and substance [4], the estimated Volatile Solids degradation and Total Solids transfer coefficients used in the modeling of LCA (Life Cycle assessment) as well as evaluating the management of garden waste from environmental aspects [2], and formed the framework of the construction material recycling flow [22].

This study aims to determine the critical MSW flow in the landfill to be repaired and developed for sustainable waste infrastructure. In addition, to design the best scenario tackling the MSW flow into the landfill based on the potential to recycle, recovery materials (compost) and recovery energy or fuel from MSW (RDF or Refuse Derived Fuel). So, the MSW residue decreased and landfill service life getting longer.

To implement these activities on a scale of TPA in order to achieve sustainable development, a model of waste materials flow needed in an integrative (MFA-STAN) based on the scenario made periodically to waste reduction activities through garbage recycle and recovery activities. By modeling and simulating multiple scenarios, it will be clearly delineated on material flow in the system, such as the weight of garbage that goes into the system (input), the flow of critical systems, the potential for waste in the landfill for doing recycle and recovery activities, the effect of doing recycle and recovery to reduction of the waste that goes to Cipayung landfill and residual garbage dumped in landfill Cipayung (output).

## LITERATURE REVIEW

### Accomplished studies

Research in waste field that using MFA STAN has been widely applied in developed countries. MFA STAN has been used to create a system of material flow in the form of mass and substance to waste management in California [10], six scenarios handling and processing of garden waste urban Aarhus, Denmark [2], and the system of material flow in the form of substance (Substance Flow Analysis or SFA) system for organic waste home composting. SFA considered is VS, ash, C, N, K, P, Cd, Cr, Cu and Pb [1]. Moreover, case studies have been researched on the scenario of urban waste management in the city of Wroclaw-Poland Europe [6].

### Waste processing technology application

**a) Composting**

According to [9], one of good raw materials for composting is organic MSW (food waste, garden waste, etc.). The main parameters of the compost raw materials which affect the composting process include C/N ratio, pH, water content, and temperature [13]. Compost standard quality that used is the Indonesian National Standard 19-7030-2004 containing the specification compost from domestic organic waste. For example, the standards for the parameters C/N ratio (10-20), Carbon (9,8-32%), nitrogen (≥0,4%), particle size (0,55-25 mm), pH (6,8-7,49) and water content (≤50%).

**b) Recycling**

Recycling program aims to reduce the waste that ends up in landfills, so it has economic value and prevents an increase in methane gas. Recycling not only reduces the need for a sanitary landfill but also recovering the raw materials that can be used for the same production or new production [17,19].

**c) RDF (Refuse derived fuel)**

According to [5], RDF is known as an alternative fuel produced from garbage combustible fraction (plastic and other materials such as textiles, wood and others). Based on [12], it is one of the waste handling techniques to convert waste into something useful, for example as fuel. RDF fraction resulting from the waste separation of combustible and non-combustible fraction mechanically.

**d) Final disposal/Final landfill**

Based on [21], there are 3 types of practical final disposal/final landfill: open dumping, controlled landfill and sanitary landfill.

## MATERIALS AND METHOD

### Location and time

Sampling located in Cipayung landfill B, Depok (West Java Province, Indonesia). MSW sampling were done for 8 consecutive days, according to SNI 19-3964-1994 [14]. To obtain a representative sample population in Cipayung landfill B, sampling conducted twice a day for 8 days (morning and afternoon).

### Data collection

Secondary and primary data, used for system modelling Cipayung landfill B with MFA-STAN.

**a) Secondary data**

- Depok inhabitants [obtained from the official website of Depok government and Central Bureau of Statistics].
- Research reports in Cipayung landfill and Depok MSW profiles (obtained from Department of Sanitation and Gardening, Depok city/DKP Depok and Unit of Technical Implementation Cipayung landfill/UPT TPA Cipayung).

**Figure-1.** Cipayung landfill B.

**b) Primary data**

- Data from Unit Waste Processing (Material Recovery Facilities/MRF) in Cipayung landfill (called MRF Hanggar TPA Cipayung), the vehicles, the frequency and the rate of waste transportation to Cipayung landfill (obtained from interviews with DKP Depok, UPT TPA Cipayung & MRF Hangar TPA Cipayung and observations as well as direct recording on location).
- Measurement of waste composition (refers to the SNI 19-3964-1994)
- The waste particle size (refer to ASTM E 828-81 (Reapproved 2004))
- Identify the type (sampling organic waste, paper, plastic, glass, aluminum and metal) and the amount of waste that has potential for recycling raw materials (questionnaires and interviews with the scavengers)
- Identify the type (sampling organic waste: kitchen and garden) and the amount of waste that has the potential for compost material (laboratory test for Moisture Content, Carbon and Nitrogen in Sanitary

Engineering and Environmental Laboratory, University of Indonesia)

- Identify the type (sampling organic waste, paper, rubber and leather, plastics, textiles, etc.) and the amount of waste that has potential for RDF raw materials (test moisture content, ash content, and volatile content in Sanitary Engineering and Environmental Laboratory, University of Indonesia also estimate the calorific value of waste based on the empirical models).

**Total sample**

- Vehicles transporting waste to Cipayung landfill

$$n = \left(t \cdot \frac{s}{e \cdot \bar{x}}\right)^2 \quad (1)$$

Note:

n = total number of vehicle samples studied
t* = t statistical value related to the desired confidence level [for example at t*95 (95%)ort*90 (90%)],
s = deviation standard,
e =desired level of precision (eg precision level of 10%, 20%); and
$\bar{x}$ = The average forecast.

$$a = \frac{n}{8} \quad (2)$$

Note:

a = number of vehicle samples every day
n = total number of vehicle samples studied
t =duration of the study (measurement of the composition according to SNI 19-3964-1994 = 8 days)

Based on calculations (where e = 10% and t*90), the number of vehicle samples studied for 8 days for this research= 144 vehicles. So that every day will be observed 18 selected vehicles randomly (9 vehicles for each morning and afternoon).

- Scavengers Cipayung landfill

Slovin formula

$$n = \frac{N}{N \cdot d^2 + 1} \quad (3)$$

Note:

n = Sample size
N = Populasi size
d = Estimation error (in this study d = 0,1)

Based on calculations, the number of samples taken from scavengers population (N=150) are 60 samples of respondents. However, questionnaires distributed are 70 respondents.

- Waste composition measurement in Cipayung landfill

Measurement refers to SNI 19-3964-1994. In this study, waste composition measurement was done by taking a sample of MSW from each vehicles that shed the MSW to Cipayung landfill B. Based on these calculations, the amount of garbage samples collected every day for composition measurement as well as laboratory test (a small portion of each total sample) is 200 kg (morning and afternoon) from 18 vehicles (each 100 kg from 9 vehicles at morning). In this study, the waste composition to be studied consist of 12 groups (organic, plastic, paper, glass, aluminum and metal, rubber and leather, composite and inert, textiles, wood, sanitary products, hazardous & toxic waste, etc.).

$$\text{Composition} = \frac{w_A}{\sum_{A=1}^{Z} w_A} \times 100\% \quad (4)$$

Note:

$W_A$ = weight of component A
Z = Number of waste components

- Waste particle size measurement in Cipayung landfill

Waste particle size was measured with two sieves (diameter of 10 mm and 50 mm). From 100 kg MSW sample for once composition measurement, taken as ± 2 kg of waste (ASTM E 828-81 (Reapproved 2004)) as samples for particle size identification.

- Waste calorific value measurement in Cipayung landfill

Waste calorific value was estimated using empirical model, which used a model based on physical composition and proximate analysis. In this study, the calorific value were only for combustible waste (paper, rubber and leather, plastics, textiles, and wood, etc.).

**Table-1.** Empirical model to predict waste energy.

| No | Analysis | Model | Formula | Note |
|---|---|---|---|---|
| 1 | Physical Composition | Conventional | $Hn = 88{,}2R + 40{,}5(G + P) - 6W$ (5) | Hn = nett calorific value (kcal/kg); R = plastic (%dry weight); G = organic (%dry weight); P = paper (%wet weight); and W = water content (%). |
| | | Khan & Abu Gharah | $E = 23(F + 3{,}6(PA)) + 160(PL)$ (6) | E = waste energy content (Btu/lb); PL = plastic (%dry weight); F = food (%dry weight); and PA = paper (%dry weight). |
| 2 | Proximate | Tradisional | $Hn = 45B - 6W$ (7) | Hn = nett calorific value (kcal/kg); B = volatile content (%dry weight); and W = water content (%). |
| | | Bento | $Hn = 44{,}75B - 5{,}85W + 21.2$ (8) | Hn = nett calorific value (kcal/kg); B = volatile content (% dry weight); and W = water content (%). |
| | | Tchobanoglous | $E = \frac{\sum C}{\sum A}$ (9) | E = waste energy content (kCal/kg); $\sum A$ = total waste weight (kg); B = energy from each waste component (kCal/kg); and $\sum C = \sum (A \times B)$ = total waste energy (kCal). |

Source: [11],[17], and [19]

- Depok inhabitants forecast

MSW generation and composition related to inhabitants/population growth.

Arithmetic method

$$P_n = P_0(1 + r\,n) \quad (5)$$

Note:
$P_0$= the number of inhabitants in the early years
$P_n$= total population in year-n
r = rate of population growth from the beginning to the year-n
n= the amount of changing year

**Analysis methods**

**a) Software MFA**

According to [3] and [8], MFA is the right tool to investigate the flow and stock-based material systems. It provides insight into the behavior of the system and when combined with other disciplines such as energy flow analysis, economic analysis, and consumer-oriented analysis, facilitates control of anthropogenic systems. The objectives are as follows.

- Describing a system of material flows and stocks with a clear definition.
- Reduce the complexity of the system.
- Assess the relevant flow and stock in quantitative terms.
- The current results on the flow and stock of a system in a way that can be reproduced, understandable, and transparent.
- Using the results as a basis for managing resources, the environment, and waste.

**b) MFA with Software STAN**

Based on [8] and [4], concerning the description of MFA by using software applications, criteria for the right software, and some considerations Based on the STAN advantages, so in this study will be selected as the software STAN MFA. STAN (The Standard for Material Flow Analysis) is a device that is free that can help display the material flow analysis based Austrian standard ÖNorm S 2096 (application-analysis of material flows in waste management).

**Model MFA-STAN**

To build the model MFA-STAN, components consist of a system boundary, processes, and flows.

- System Boundary
- Define in space and time which data considered. The spatial system boundary could be the logistical border of a company or the spatial border of a region in time.
- Processes
  Processes might contain stocks or sub systems that can be described by an extra model.
- Flows
  There is a flow of imports / inputs (internal flow linking process into the system) and exports or output streams (streams that cross system boundaries).

**Model calculation MFA STAN**

- Calculation Algorithm

To illustrate by means of mathematical models, there are 3 main types of equations used (equilibrium equations).

- Mass conservation

The mathematical equation used for the conservation of mass balance equations and stock.
Balance equation:

$$\sum \text{Inputs} = \sum \text{Outputs} + \text{Change in stock} \quad (6)$$

Stock equation:

$$\text{Stock}_i = \text{Stock}_{i-1} + \text{Change in stock}_{i-1} \quad (7)$$

Note:
Stock $_i$ = Stock $_{i-1}$+ **Change in stock** $_{i-1}$; i = periods

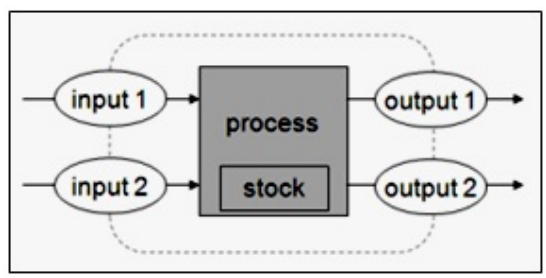


**Figure-2.** Mass conservation source[4].

- Linear relations

Linear relation such as Transfer Coefficient (TC) equation. The transfer coefficient TCx,j describes the partitioning of a material (good or substance) x within a process, and it's transfer into a specific output flow j.The sum of the transfer coefficients to all output flows must be 1, considering that transfers into the stocks are also counted as outputs.

$$\text{Output}_1 = \text{TC}_1 \times \text{Total}_{\text{Input}}$$
$$\text{Output}_2 = \text{TC}_2 \times \text{Total}_{\text{Input}}$$
$$\text{TC}_1 + \text{TC}_2 = 1 \quad (8)$$

Additional linear relation equation between similar quantities

$$\text{Flow}_Z = \text{Factor} \times \text{Flow}_Y$$

- Concentration equation

$$\text{Mass substance} = \text{mass good} \times \text{concentration substance} \quad (9)$$

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$$\text{Mass substance} = \text{volume good} \times \text{concentration substance} \quad (10)$$

$$\text{Mass good} = \text{volume good} \times \text{density good} \quad (11)$$

- Data uncertainty

STAN allows the consideration of data uncertainties. It is assumed that uncertain quantities are normally distributed, given by their mean value and standard deviation. This approximation offers the possibility to use methods like error propagation and data reconciliation. e.g. normally distributed random quantity with mean value 100 and standard deviation 20. The standard uncertainty is calculated by dividing the standard deviation by the square root of the sample number.

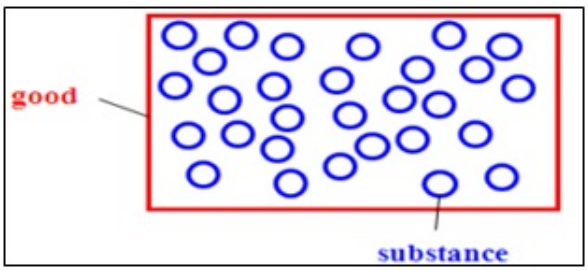


**Figure-3.** Good and substance source[4].

- Error propagation

The method of error propagation is part of the algorithm for data reconciliation that is performed automatically when calculating with STAN.

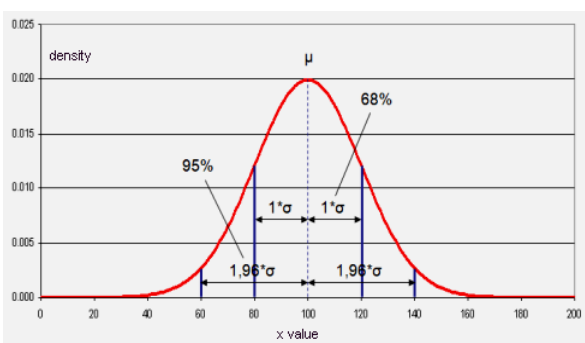


**Figure-4.** Normal distribution.

- Data reconciliation

There are two necessary conditions can be solved by data reconciliation:

- The system of equations has to be over determined (more independent equations than unknown variables).
- Some of the given data have to be normally distributed.

$$SY^2 \approx \left(\frac{\partial Y}{\partial X_1}\right)^2_{\bar{X}_1,\bar{X}_2,\ldots} \cdot SX_1^2 + \left(\frac{\partial Y}{\partial X_2}\right)^2_{\bar{X}_1,\bar{X}_2,\ldots} \cdot SX_1^2 + \cdots \quad (12)$$

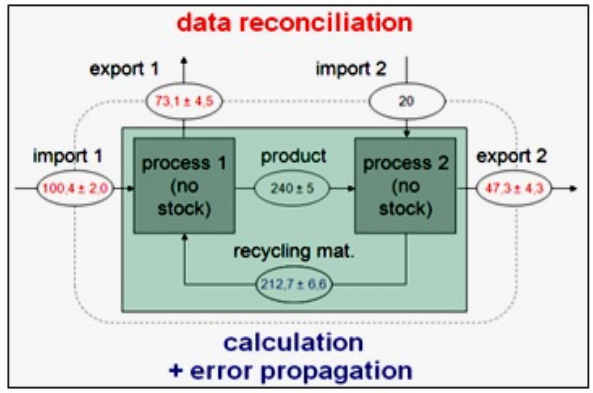


**Figure-5.** Data reconciliation.

During data reconciliation the mean values of uncertain data will be altered in a way that contradictions disappear. A solution is found when the sum of squares of the necessary chances reaches a minimum (method of least squares). The variances (square of standard deviation) of the uncertain quantities are used as weighing factors. As additional effect of data reconciliation the uncertainty of the reconciled data is reduced.

**c) MFA-STAN modeling duration**

The duration used for modeling MFA-STAN in this study is for every 1 year for 5 years in period (2014-2019). Time modelling has been based on [7] regarding the time for efforts to optimize waste management program at the landfill Cipayung.

**d) Scenarios design**

Scenarios are designed to determine the best management in terms of reducing waste to be dumped into landfill and the longest in terms of extending the service life of the landfill Cipayung age. Besides that, to determine the potential for recycling and recovery at the landfill boundary Cipayung system. Scenarios done through modification and improvement of existing condition.

**a) Existing condition**

The existing condition of the waste management system in the landfill Cipayung, Depok still be just receiving, recording, structuring and compacting rubbish in Cipayung. So MSW is still very much that has not been empowered. MSW sorting is still done manually by scavengers. It is assumed there will be an increase in the number of scavengers each year which would affect the increased amount of waste segregation. Further input into sub garbage landfill MRF Hangar Cipayung system that has not reached the design capacity of the MRF as well as composted and recycled raw materials (still very low activities).

**b) Scenario 1**

To optimize MRF Hangar Cipayung capacity and increase TPA Cipayung also empower of sorting MSW in Cipayung landfill B for recycling. The assumptions used for MFA-STAN modelling scenario 1 as follows.

- Waste composition assumed to be fixed or unchanged
- The amount of scavengers assumed to be increasing at ± 5% per year [7]
- Waste input that flow to sub-system MRF Hangar Cipayung assumed to remain and achieve maximum capacity MRF (input = 30 $m^3$/day/MRF, organic = 18 $m^3$/day/MRF, inorganic = 3 $m^3$/day/MRF and residue to landfill = 9 $m^3$/day/MRF)

**c) Scenario 2**

Efforts to optimize and increase the number of MRF Hangar Cipayung landfill, improve and empower of MSW sorting in Cipayung landfill B for recycling.The assumptions used for MFA-STAN modelling scenario 2 as follows.

- Waste composition assumed to be fixed or unchanged
- The amount of scavengers assumed to be increasing at ± 10% / year [7]
- Waste input that flow to sub-system MRF Hangar Cipayung assumed to remain and achieve maximum capacity MRF (input = 30 $m^3$/day/MRF, organic = 18 $m^3$/day/MRF, inorganic = 3 $m^3$/day/MRF and residue to landfill = 9 $m^3$/day/MRF)
- The addition of MRF Hangar TPA Cipayung
- Setting for the pattern and MSW transportation assumed by 20% flow to MRF Hangar Cipayung[16].

**d) Scenario 3**

Efforts to optimize and increase the number of MRF Hangar Cipayung landfill, increase recycling at TPA Cipayung B, improveme and empower of MSW sorting that not disaggregated for recycling raw materials and RDFraw materials. The assumptions used for MFA-STAN modelling scenario 3 as follows.

- Waste composition considered to be fixed or unchanged.
- The amount of scavenger assumed to be increasing at ± 10% / year [7]
- Waste input that flow to sub-system MRF Hangar Cipayung assumed to remain and achieve maximum capacity MRF (input = 30 $m^3$/day/MRF, organic = 18 $m^3$/day/MRF, inorganic =3 $m^3$/day/MRF and residue to landfill = 9$m^3$/day/MRF)
- The addition of MRF Hangar TPA Cipayung
- Empower disaggregated MSW at Cipayung landfill B as RDF raw materials
- Setting for the pattern and MSW transportation assumed by 20% flow to MRF Hangar Cipayung [16].

## RESULTS AND ANALYSIS

**Waste characteristics in Cipayung landfil B**

- Physical characteristics
  - Waste density, 220,44 kg/$m^3$.
  - The particle size, Ø > 50 mm (62,875%), 10 mm < Ø < 50 mm (30,606%), and Ø < 10 mm (6,519%).
  - The water content for organic 70,704%, wood 26,894%, textile 26,181%, paper 21,126%, plastic 19,895%, others 16,448% and rubber-leather 12,514%.
  - MSW composition could be seen in figure-6. The most composition is organic waste.
- Chemical characteristics
  - Volatile content for paper 68,481%, plastic 66,093%, others 63,601%, rubber-leather 63,566%, wood 56,719%, textile 47,491% and organic22,666%.
  - Ash content for organic 2,073%, paper 5,563%, others 8,459%, wood 10,291%, plastic 10,6075%, rubber-leather (15,545%) and textile 19,946%.
  - Carbon (C) and Nitrogen (N) content for organicis 40,068% and 1,529%.
  - C/N ratio for organic is 26,119:1.
  - Calorific value for combustible waste is 2.755,63-6.552,25 kCal/kg (calculation based on empirical model by using formula 5 untill 9, the result could be seenin Table-2).

**Table-2.** Calorific value for combustible MSW based on empirical model.

| Model | Calorific Value (kCal/kg) |
|---|---|
| Konvensional | 5.679,53 |
| Khan and Abu Gharah | 6.552,25 |
| Tradisional | 2.755,63 |
| Bento | 2.763,88 |
| Tchobanoglous | 4.521,27 |

The rate of Depok MSW transportation to Cipayung landfill = 217 tonnes/day. The rate of Depok MSW collection to landfill = 0,52 liters/person/day or 0,11 kg/person/day. While the level of Depok MSW serviceability transport to Cipayung landfill is 19,57%. MSW critical flow in the landfill to be repaired and developed for sustainable MSW infrastructure contained in the composition of organics (65,75%) and plastics (11,937%).

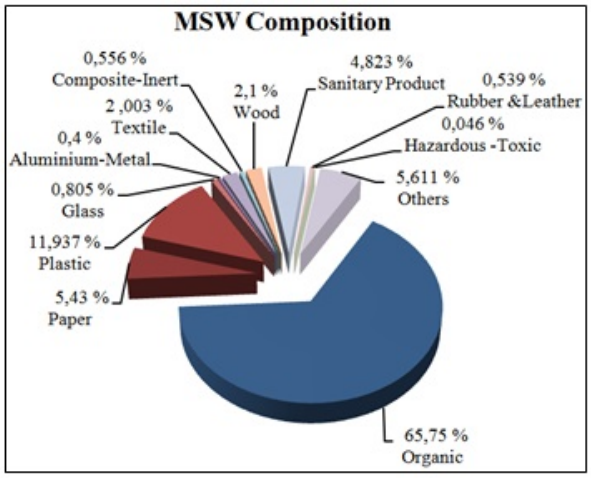


**Figure-6.** MSW composition.

**Waste potential as resource**

Based on MSW characteristics, MSW in TPA Cipayung potentially for recycling 25,417%, composting 58,906% and RDF 27,619%. MSW collector-stalls (named Lapak) management in TPA Cipayung needed to be disciplined and collaborated by UPT TPA Cipayung and Depok government.

**Table-3.** Potential for implementing waste processing technology in Cipayung landfill.

| No | Component | Composition (%) | Recycling (%) | Composting (%) | RDF (%) | Final Landfilling (%) |
|---|---|---|---|---|---|---|
| 1 | Organic | 65,750 | 6,844 | 58,906 | | 65,750 |
| 2 | Paper | 5,430 | 5,430 | | 5,430 | 5,430 |
| 3 | Plastic | 11,937 | 11,937 | | 11,937 | 11,937 |
| 4 | Glass | 0,805 | 0,805 | | | 0,805 |
| 5 | Aluminium-Metal | 0,401 | 0,401 | | | 0,401 |
| 6 | Textile | 2,003 | | | 2,003 | 2,003 |
| 7 | Composite-Inert | 0,556 | | | | 0,556 |
| 8 | Wood | 2,099 | | | 2,099 | 2,099 |
| 9 | Sanitary Product | 4,823 | | | | 4,823 |
| 10 | Rubber-Leather | 0,539 | | | 0,539 | 0,539 |
| 11 | Hazardous-Toxic | 0,046 | | | | 0,046 |
| 12 | Others | 5,611 | | | 5,611 | 5,611 |
| | Total (%) | 100 | 25,417 | 58,906 | 27,619 | 100 |

MSW potential in Cipayung landfill for RDF raw materials will allow the formation of a partnership with the private sector and industry. For example with the cement industry. Raw material compost can be also used as material for the landfill cover soil (besides as fertilizer).

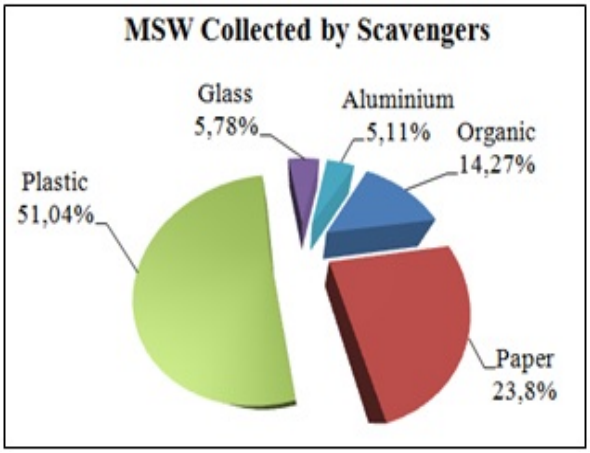


**Figure-7.** MSW collected by scavengers.

MSW residues must be still processed by using mechanical equipment such as tromel so that it will be able to increase the sorting of waste for recycling, composting and RDF product. For example, by using tromel capacity of 17 tons/hour.

**Figure-8.** Potential for recycling.

**Figure-9.** Potential for composting.

**Table-4.** MSW potential to be RDF raw materials based on international standard.

| Parameter | Turki | Lechtenberg (Jerman) | Europe | Finlandia | Italia | England | TPA Cipayung |
|---|---|---|---|---|---|---|---|
| Water content (% dry weight) | 25 | <20 | <25 | 25-35 | 25 | 7-28 | 20,28 |
| Volatile content (% dry weight) | 92,3 | 50-80 | - | - | - | - | 63,94 |
| Volatil content (% wet weight) | - | - | - | - | - | - | 50,97 |
| Ash content (% dry weight) | 7,7 | 8-12 | - | - | - | - | 36,06 |
| Ash content (% wet weight) | - | - | <5 | 5-10 | 20 | 12 | 28,75 |
| Calorific value (kCal/kg) | 3.500 | - | 3.585 | 3.107-3.824 | 3.585 | 4.469 | 2.755,63-6.552,25 |

Based on the modelling by using MFA STAN, resulted that scenario 3 is the best of all to be implemented in Cipayung landfill. Scenario 3 could significantly decrease (> 50 % reduction) the MSW residue to be landfilled. If the technologies apply seriously and consistently, Cipayung landfill will reach zero waste condition. It's beacause of the MSW optimization and utilizatition became resources. Recapitulation in the early stages of planning (2014) and the end of the plan (2019) conducted to see the changes and the effect of recycling and recovery of waste in Cipayung landfill based on the scenarios.The recapitulation could be seen in Table-5 and figures below. In MFA STAN model (Figure-11 until Figure-14) could be seen that the largest shankey at organic waste in material flow. It indicates that organic waste should be paid attention for its critical flow which must be more managed and empowered. So that TPA Cipayung life span getting longger.

**Figure-10.** Potential for RDF.

MSW management system in TPA Cipayung, Depok needs to be improved, integrated also sustainabled between the UPTTPA Cipayung, MRF Hangar TPA Cipayung, Waste collectors-stalls and Scavengers. So that

MSW not only dumped into the final landfill area, but treated as a resources.

**Table-5.** MFA STAN modelling results (especially for 2014 and 2019).

| Year | Condition | Input to system boundary TPA Cipayung | Input to sub system boundary TPA Cipayung | | | | | | Output from system boundary TPA Cipayung |
|---|---|---|---|---|---|---|---|---|---|
| | | | Cipayung landfill | | | MRF Hanggar Cipayung | | | |
| | | | Input | Output | | Input | Output | | |
| | | Waste weight (ton/annum) | Waste weight (ton/annum) | Recycling raw material (ton/annum) | RDF raw material (ton/annum) | Waste weight (ton/annum) | Compost raw material (ton/annum) | Recycling raw material (ton/annum) | Residue to Cipayung landfill B (ton/annum) |
| 2014 | Existing | 64930,042 | 60062,727 | 1994,44 | - | 4867,32 | 2920,389 | 486,732 | 59528,478 |
| | Scenario 1 | 64930,042 | 57629,069 | 1994,44 | - | 7300,97 | 4380,584 | 730,097 | 57824,918 |
| | Scenario 2 | 64930,042 | 52153,340 | 2082,80 | - | 12776,70 | 7666,021 | 1277,670 | 53903,546* |
| | Scenario 3 | 64930,042 | 52153,340 | 2082,80 | 12845,98 | 12776,70 | 7666,021 | 1277,670 | 41057,563** |
| 2019 | Existing | 77423,503 | 72556,187 | 2499,37 | - | 4867,32 | 2920,389 | 486,732 | 71517,017 |
| | Scenario 1 | 77423,503 | 70122,530 | 2499,37 | - | 7300,97 | 4380,584 | 730,097 | 69813,456 |
| | Scenario 2 | 77423,503 | 62821,557 | 3029,53 | - | 14601,95 | 8761,167 | 1460,195 | 64172,607* |
| | Scenario 3 | 77423,503 | 62821,557 | 3029,53 | 15084,01 | 14601,95 | 8761,167 | 1460,195 | 49088,593** |

* = scenario 2 could be considered to be implemented in TPA Cipayung
** = scenario 3 considered to be implemented in TPA Cipayung, because of utilizing MSW and decreasing the residue significantly

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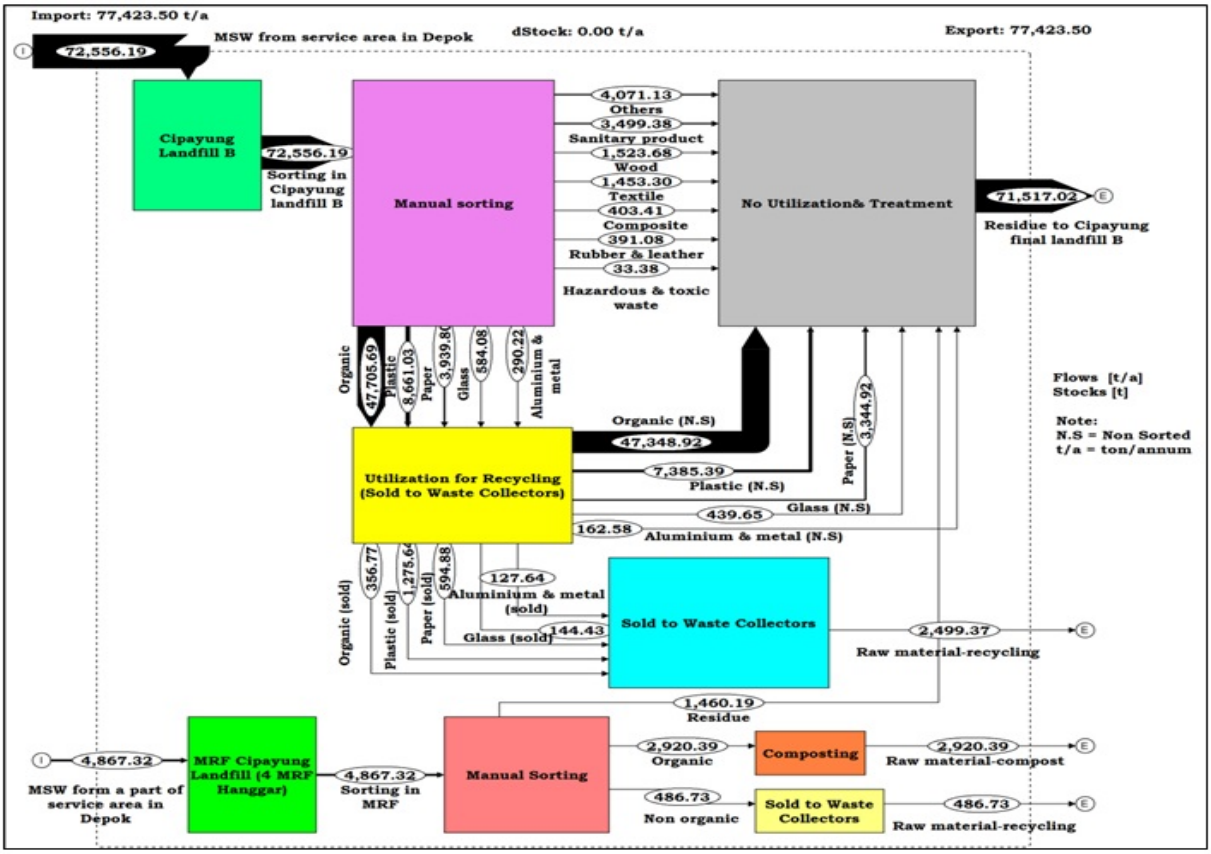


**Figure-11.**MFA STAN model for existing condition (predicted in 2019).

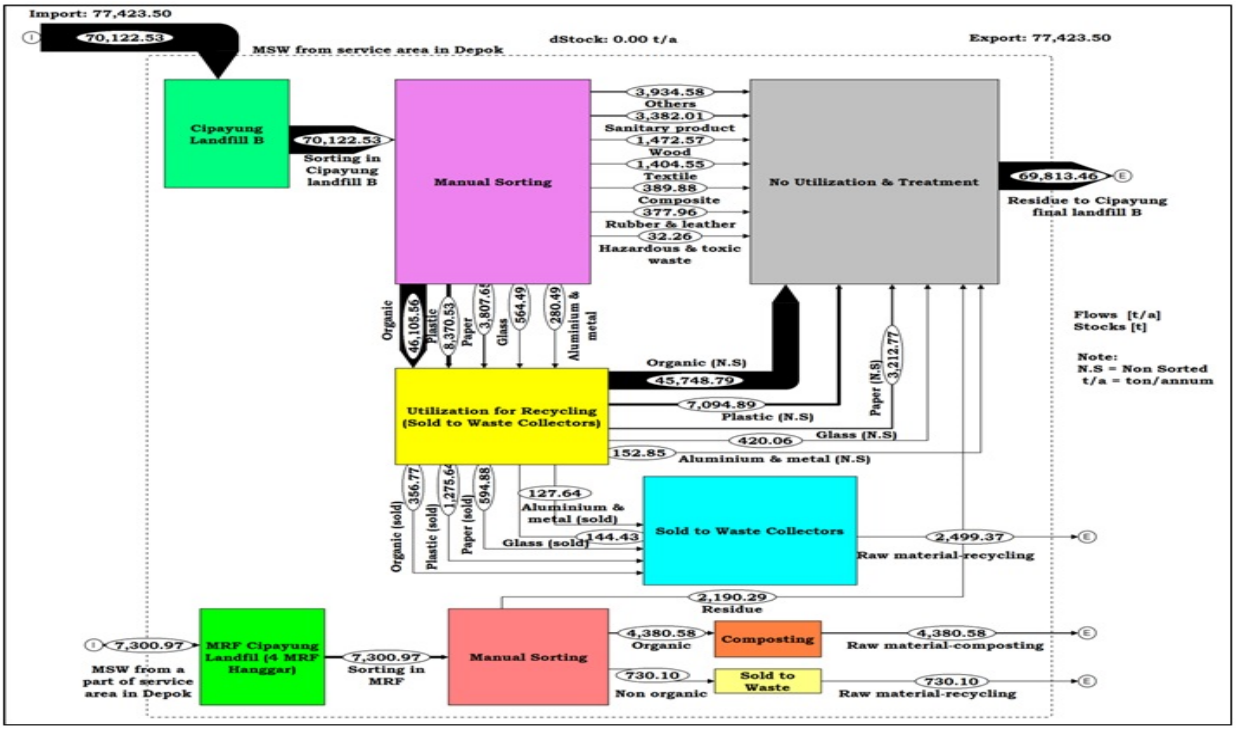


**Figure-12.** MFA STAN model for scenario-1 condition (predicted in 2019).

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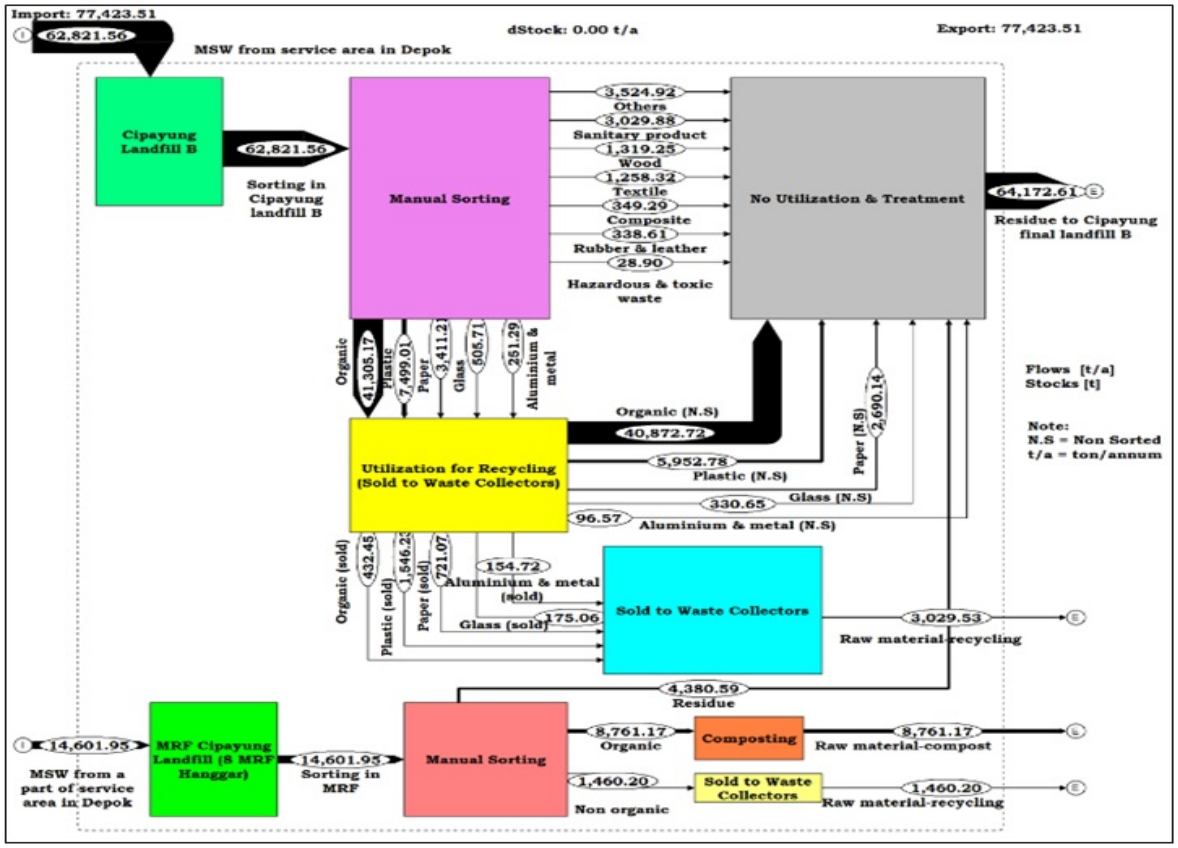


**Figure-13.** MFA STAN model for scenario 2 condition (predicted in 2019).

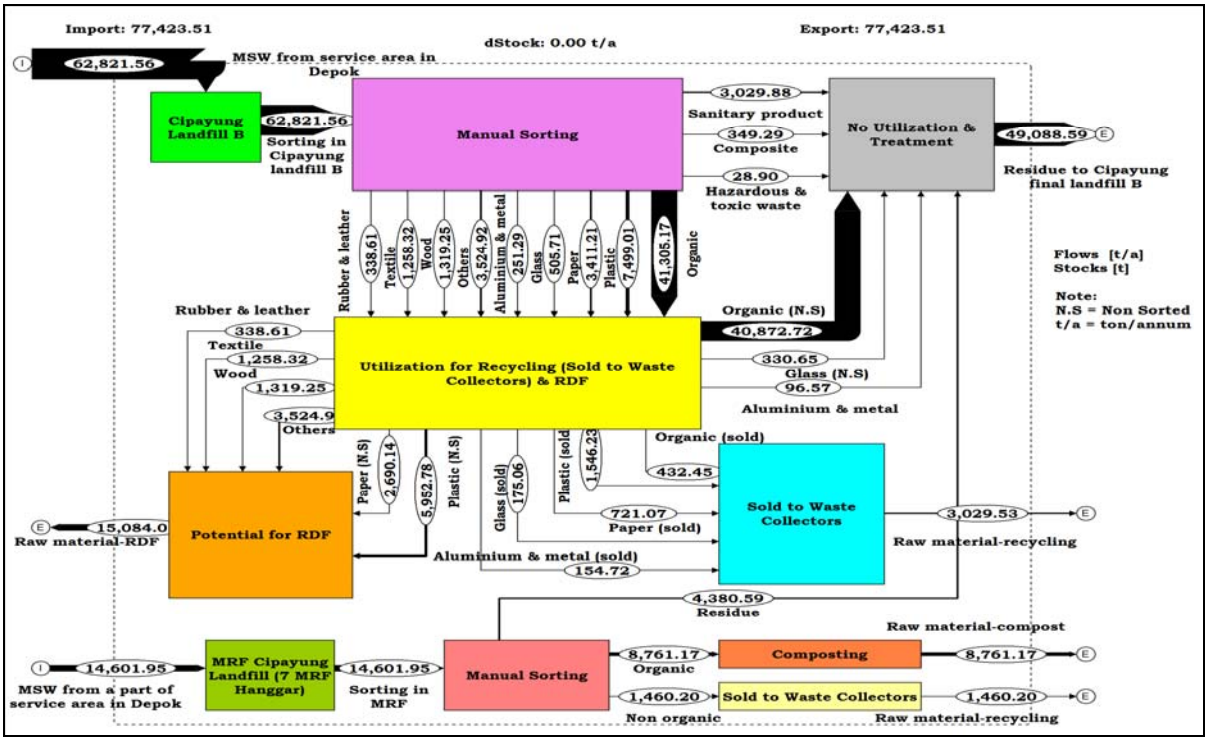


**Figure-14.** MFA STAN model for scenario 3 condition (predicted in 2019).

## CONCLUSIONS

- Based on laboratory tests and surveys, waste processing technology potentially applicated by composting (58,906%), recycling (25,417%) and RDF (27,619%).
- Scenario 3 (the optimization of composting, improved sorting, recycling and RDF) is appropriate scenario to reduce MSW to be dumped (about more than 50%) also to increase the lifespan of serviceability landfill.

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