Circular Economy on Non-Biodegradable Waste Management with MASARO Technology

A Z Abidin1*, E V Yemensia1, K W Wijaya1, and A P Rahardjo1

1 Department of Chemical Engineering, Bandung Institute of Technology, Jl. Ganesha 10, Bandung 40132, Indonesia

*Email: zainal@che.itb.ac.id / mitraiqro@yahoo.com

Abstract. The study was based on Indonesia and global waste management issue especially on non-biodegradable waste handling and the circular economy of the method to solve the problem. Non-biodegradable waste is a problem in the world and its management especially for non-recycled waste does not reflect the circular economy principle and not environmentally friendly. This needs a new method that can process this type of waste through an environmentally friendly recovery process. Zero Waste Management/Manajemen Sampah Zero (MASARO) technology presents a solution to this problem by processing non-recycled non-biodegradable waste through a plastic refinery unit in Non-Biodegradable Waste Management Installation/Instalasi Pengolahan Sampah Anorganik (IPSA). The application of the circular economy principle has been carried out in this MASARO plastic refinery where All non-biodegradable waste is processed into other useful products, such as: fuel, planting media, wood preservatives and organic pesticides. There is no non-biodegradable waste ended up in Temporary Waste Site (TPS) and Final Landfill (TPA). Therefore, MASARO plastic refinery is an environmentally friendly solution for non-biodegradable waste and suitable for sustainable development.

1. The first section in your paper

Indonesia has serious problem regarding Municipal Solid Waste (MSW) that keep increasing from year to year. World Bank estimates that the amounts of MSW generated by urban area is 85.000 tons daily. Among the top polluter, Indonesia is ranked second behind China when it comes polluting ocean with plastics [9]. The current waste problem is quite serious considering the increasing volume waste produced along with handling cost.

The problem of non-biodegradable waste management now is not only the absence or not updated technology of waste management facilities but also the attitude and the behavior of the citizen that do not reflect waste management itself. Most of the garbage is often mixed up between organic waste and non-biodegradable waste when throwing to the trash can. Non-biodegradable waste is divided by two group, recycled plastic waste and un-recycled waste. Recycled waste often sold to recycling industry to be converted into new product while un-recycled waste is transported every week to TPS/TPA area. The garbage is then only stockpiled in TPS and TPA so that this activity does not deal with the problem of waste because the waste is only moved and not processed.

Non-biodegradable waste can be divided by two: (1) un-recycled plastic waste and (2) other un-recycled non-biodegradable waste. Unrecycled plastic waste has been a concern in the world for many decades, as it is non-biodegradable polymers mostly containing carbon, hydrogen, and few other elements such as chlorine, nitrogen, etc [1]. Un-recycled plastic waste is includ plastic film Recycling plastic has proven difficult and can be costly because of the constraints on water contamination and
inadequate separation prior to recycle that is labor intensive [2]. Other type of un-recycled waste can be considered as waste to energy. The waste included dirty paper woods, tissue, fabric, leather, diaper. This type of waste is processed by burning it in incenerator. The waste cannot be recycled again but contain a lot of energy. By burning this waste as energy sources for other waste processing such as pyrolysis.

Plastics come in different types, and not all of them can be recycled. Hence, separation is needed since plastics are made of different resin compound, transparency, and color [3]. Clearly transparent plastics are often desirable by the manufacturers since they can be dyed to transform into new products, thus have greater flexibility. Pigmented or dyed plastics have lower market value, and sometimes cannot be recycled [4]. Plastic waste management is needed to overcome this problem. Plastic pyrolysis is one of the solution to overcome plastic waste problem. Pyrolysis is the process of thermally degrading long chain polymer molecules into smaller, less complex molecules through heat and pressure [5]. This process is a part of de-polymerization, which is in contrast to the production of plastics, which uses polymerization of syngas and crude oil [6]. The process requires intense heat with shorter duration and in absence of oxygen. The major products from pyrolysis process are oil, gas, and char which are valuable for industries [3]. The liquid oil produced can be used as fuel for furnaces, boilers, turbines, and diesel engines without the needs of upgrading or treatment [7]. Pyrolysis does not cause water contamination and is considered as green technology [8].

MASARO (Management Sampah Zero) is a zero waste management system that offers the handling of waste until it is fully reduced to zero. MASARO change the old paradigm "collect and transport waste" or "reduce-reuse-re-cycle" in waste management system into a new paradigm of "sort-collect-process-sell" without producing waste that pollutes the environment. 100% of waste is processed and becomes valuable products, and hence MASARO needs no more TPS/TPA area that currently are big problems. Certainly this reflects the real circular economy application that is now promoted all over the world. The purpose of this paper is to show the system and technology MASARO for non-biodegradable waste is one of the best solution for handling waste because it has provide environmentaly friendly technology and also represent the circular economy.

2. Method
The circular economic of the non-biodegradable waste processing with MASARO Plastic Refinery Technology is carried out by reviewing several aspects of the waste processing process according to circular economic principles [10] including:

1. Renewable sources are continually being regenerated over time. [10]
2. Fast trade enables optimal use and access of products and assets. [10]
3. Increase product life by designing products to be durable. [10]
4. Associated value chains that produce no waste. [10]

Considering that waste is an environmental issue, it is necessary to consider environmentally friendly aspects in the waste management process. To produce a circular economic process of environmentaly friendly waste processing technology, it is necessary to analyze the MASARO plastic refinery technology in the form of:

1. The reduction of environmental and health quality caused by incineration waste, including the emission of CO2, SOx, NOx, and ash (fly ash and precipitation) [11]
2. Global warming effect caused by CO2 production. [11]
3. Acid rain potential or acid deposition by SOx and NOx oxidation that can cause the reduce the life and population of water ecosystem, as well as reduce soil nutrient. [11]
4. Nearby air pollution caused by dust particulate, smoke mist, and the formation of bad ozone caused by photochemical reaction of NOx with volatile organic compound that can harm health [11]
5. Dioxins content in flue gas that releases to the environment which can cause cancer, damage the immune system and growth.
MASARO plastic refinery analyst data was analyzed by the third party comprise: (1) flue gas of environmental standard test was tested by Sucofindo (Table 1 and Table 2), (2) dioxins content was tested by CRL Calabarquez Corporation (Table 3), (3) waste water environmental standard test was tested by Sucofindo (Table 4).

Basically, non-biodegradable waste management in MASARO consists of five principles as follows:

1. At source separation;
2. At source treatment;
3. Involving Society, Government, and Industry: (society to do separation at sources, government to provide facility and treat the hazardous waste, and industries to recycle the waste);
4. Educating the people to separate and treat the waste at source;
5. Applying the appropriate environmentally friendly technology.

The first step in non-biodegradable waste processing with MASARO technology is waste sorting on source to classify waste into 3 categories, in which are: recycled waste, un-recycled plastic waste, and other un-recycled waste. Non-biodegradable Waste that has been sorted is completely processed in IPSA by MASARO plastic refinery without any waste dumped into TPS/TPA. Non-biodegradable waste processing in MASARO involve the participation of the community, government and industry where MASARO changes the habits and behavior of the community in waste processing, the government as Masaro's technology provider in waste processing and industry in further processing recycle waste. MASARO technology convert non-biodegradable waste into a valuable products such as fuel, polybag farming growing medium, organic pesticide, and wood preservative. This MASARO system will transform waste processing that was originally cost center into a profit center waste management. The non-biodegradable waste management by MASARO technology is presented in Figure 1.

![Figure 1. MASARO non-biodegradable waste management.](image)

Circular economy of MASARO Non-biodegradable Waste Management is also carried out by studying the case of the implementation of MASARO non-biodegradable waste processing unit in MAN 2 Cirebon and Babakan Ciwaringin Village.

3. Results and Discussion

3.1. Masaro Plastic Refinery in Non-biodegradable waste processing

MASARO technology presents a solution to non-biodegradable waste problem by processing non-recycled non-biodegradable waste through a plastic refinery unit. MASARO plastic refinery divides non-recycled non-biodegradable waste into two groups, such as low value plastic waste (plastic film, thermosetting plastic, biodegradable plastic, and other plastics which are of poor quality) and waste to energy. The plastic refinery consists of a incinerator, pyrolyzer, and wet scrubber.

The incinerator burn waste such as woods, diapers, unrecycled papers, and etc that classified as waste to energy (WTE) garbage. The feed is fed into the incinerator chamber by a conveyor to prevent the smoke from garbage burning release into the environment and to ensure the safety of the production.
process. The incinerator is designed with utilizes the buoyancy force of air that make oxygen flow into the furnace chamber naturally, that make the operation process does not require any external energy source, only requires a match. The flue gas temperature of this incineration process is about 800-1000°C and will be contacted with pyrolizer chamber directly. The low value plastic waste will be process in pyrolyzer that installed vertically with the incinerator to maximizing exhaust gas heat for the pyrolysis process and preventing heat loss during the process. The fuel vapor flows into condenser by the top of pyrolyzer and being cooled along the spiral condenser pipe until the fuel is produced. The exhaust hot gas flowing through the output pipe that connected the pyrolizer and wet scrubber. Water injection is carried out along the pipe to reduce the temperature of the exhaust gas and to dissolve the solid particles contained in the exhaust gas. The exhaust gas cleaning process is carried out on the wet scrubber unit. In the wet scrubber room, the gas will be contacted with water so that the toxic gas and dirt particles in the exhaust gas are absorbed by water and the resulting clean air can be discharged into the environment through the chimney pipe.

MASARO plastic refinery has four configurations based on waste processing capacity. The unit configuration consists of one to four incinerators and pyrolyzers with each incinerator processing capacity of 4m$^3$/hour. MASARO plastic refinery configuration with two and four incinerator and pyrolyzer unit configurations is presented in Figure 2.

![Figure 2. MASARO plastic refinery configurations (a) two incinerator and pyrolyzer unit, (b) four incinerator and pyrolyzer unit.](image)

MASARO plastic refinery processes waste into a product without any residue. All non-biodegradable waste can be processed into useful products in the form of fuel, planting media, wood preservatives and organic pesticides. The fuel comes from processing low-value plastic films in pyrolyzers, planting media is the ash from incinerator processing, and wood preservative and large organic pesticides from wet scrubber wastewater treatment.

MASARO plastic refineries have been tested to be safe and environmentally friendly. Tests have been carried out to ensure that the exhaust gas and waste water from the MASARO plastic refinery are safe to be released to environment. The combustion process which is carried out at high temperatures also does not produce dioxins which has also been tested based on laboratory results. The test results are shown below in tables 1-4.

**Table 1. Result of flue gas test in MAN 2 Cirebon by Sucofindo (2019) [11].**

*Kep-03/BAPEDAL/09/1995*
| Parameter               | Unit     | Result | Quality Standard | Method            |
|------------------------|----------|--------|------------------|-------------------|
| Particulate           | mg/Nm³   | 49.6   | 50               | Gravimetric       |
| Sulfur Dioxide (SO₂)  | mg/Nm³   | 6.2    | 250              | Electrometric     |
| Nitrogen Oxide (NO₂)  | mg/Nm³   | 4.1    | 300              | Electrometric     |
| Hydrogen Fluoride (HF)| mg/Nm³   | <0.1   | 10               | SNI 19-7117.9-2005|
| Carbon Monoxide (CO)  | mg/Nm³   | 102    | 100              | Electrometric     |
| Hydrogen Chloride (HCl)| mg/Nm³ | 0.4    | 70               | SNI 19-7117.8-2005|
| Total Hydrocarbon (CH₄)| mg/Nm³ | 11.3   | 35               | Electrometric     |
|                        |          |        |                  |                   |
| Metals:                |          |        |                  |                   |
| Arsen (As)             | mg/Nm³   | <0.01  | 1                | SNI 7117.20-2009  |
| Cadmium (Cd)           | mg/Nm³   | <0.02  | 0.2              | SNI 7117.20-2009  |
| Chromium (Cr)          | mg/Nm³   | <0.2   | 1                | SNI 7117.20-2009  |
| Plumbum (Pb)           | mg/Nm³   | <0.1   | 5                | SNI 7117.20-2009  |
| Mercury (Hg)           | mg/Nm³   | <0.004 | 0.2              | SNI 7117.20-2009  |
| Thallium (Th)          | mg/Nm³   | <0.02  | 0.2              | SNI 7117.20-2009  |
| Opacity                | %        | 20     | 10               | SNI 19-7117.11-2005|

< : Less than the detection limit indicated

**Table 2.** Result of flue gas test in MAN 2 Cirebon by Sucofindo (2019) [11].

| Parameter       | Unit  | Result | Quality Standard | Method     |
|-----------------|-------|--------|------------------|------------|
| O₂              | %     | 10.3   |                  |            |
| CO₂             | %     | 1.78   |                  |            |
| Gas Temperature | °C    | 60.0   |                  |            |
| Barometer Pressure | mmHg | 757.6 |                  |            |
| Gas Velocity    | m/sec | 9.76   |                  |            |
| Pressure        | hPa   | 0.52   |                  |            |

**Table 3.** Result of flue gas dioxins content in MAN 2 Cirebon by CRL Calabarquez Corporation (2019)

| Parameter          | Unit      | Run 1 | Run 2 | Run 3 | Average result | NESSAP standard |
|--------------------|-----------|-------|-------|-------|----------------|-----------------|
| PCDDs/PCDFs        | µg/kgm³   | 0.216 | 0.04  | 0.04  | 0.099          | 0.1             |

**Table 4.** Result of waste water test in MAN 2 Cirebon by Sucofindo (2019) [11].

| Parameter          | Unit      | Result | Quality Standard | Method     |
|--------------------|-----------|--------|------------------|------------|
| Temperature        | °C        | 34.45  | 38               | 2550B      |
| Total Dissolved Solid | mg/L   | 402    | 2000             | 2540C      |
| Total Suspended Solid | mg/L   | 136    | 200              | 2540D      |
| Iron               | mg/L      | 3.11   | 5                | 3111B      |
| Manganese          | mg/L      | 0.1    | 2                | 3111B      |
| Barium             | mg/L      | < 0.12 | 2                | 3111D      |
| Copper             | mg/L      | < 0.02 | 2                | 3111B      |
| Zinc               | mg/L      | 0.16   | 5                | 3111B      |
| Chrom Hexavalent   | mg/L      | < 0.02 | 0.1             | 3500 Cr-B  |
| Chrom Total        | mg/L      | < 0.04 | 0.5             | 3111B      |
| Parameter    | Units | Result | Quality Standard | Method  |
|--------------|-------|--------|-----------------|---------|
| Cadmium      | mg/L  | < 0.003| 0.05            | 3111B   |
| Mercury      | mg/L  | < 0.0008| 0.002           | 3112B   |
| Lead         | mg/L  | < 0.02 | 0.1             | 3111B   |
| Tin          | mg/L  | < 0.3  | 2               | 3111B   |
| Arsen        | mg/L  | < 0.002| 0.1             | 3114C   |
| Selenium     | mg/L  | < 0.001| 0.05            | 3114C   |
| Nickel       | mg/L  | < 0.04 | 0.2             | 3111B   |
| Cobalt       | mg/L  | < 0.04 | 0.4             | 3111B   |
| Cyanide      | mg/L  | < 0.01 | 0.05            | 4500-CN-E |
| Sulfide      | mg/L  | < 0.01 | 0.2             | 4500-S²-D |
| Fluoride     | mg/L  | 0.19   | 0.4             | 4500-F-D |
| Free Chlorine| mg/L  | < 0.01 | 0.05            | 4500-Cl₂-G |
| Ammonia      | mg/L  | < 0.05 | 0.5             | 4500-NH₃-F |
| Nitrate      | mg/L  | 11.03  | 2               | 4500-NO₃-B |
| Nitrite      | mg/L  | 0.28   | 1               | 4500-NO₂-B |
| BOD5 20°C    | mg/L  | 362    | 50              | 5210B   |
| COD by Potassium|      | 1208  | 100             | 5220B   |
| Dichromate   |       |        |                 |         |
| Surfactant   | mg/L  | 0.53   | 5               | 5540C   |
| Phenol       | mg/L  | 1.07   | 0.5             | 5530C   |
| Oil and Grease|      | 10    | 10              | 5520B   |

The flue gas analysis were done by Sucofindo as shown in Table I and II above. All aspects from gas meet the environmental standard, which means that incineration unit and wet scrubber unit are working well. The analysis results also showed all aspects from waste water in Table IV meet the environmental standard, except the values of nitrate, phenol, and COD by potassium dichromate. These parameters need to bring down by using waste water treatment [11]. Another test that were done in MASARO plastic refinery in MAN 2 Cirebon is dioxins content by CRL Calabarquez Corporation as shown in Table III. The analysis results showed dioxin content in flue gas lower than the standard by NESSAP which means the waste is burned in high temperature in incinerator chamber.

3.2. Masaro Non-biodegradable Waste Management in MAN 2 Cirebon and Babakan Ciwaringin Village

The waste problem in MAN 2 Cirebon and Babakan village is not only because of the absence of waste management facilities but also attitude and behavior that do not reflect the waste management itself. There is still a lot of waste scattered around the school environment and school residents are still throwing garbage mixed up/no waste sorting. MAN 2 Cirebon has a temporary trash shelter located at the back of the school. Non-biodegradable waste is transported every week using a garbage truck to the landfill area located in Indramayu, Arjawinangun, and Majalengka. The garbage is then only stockpiled so that this activity does not deal with the problem of waste because the waste is only moved and not processed. MAN 2 Cirebon spends around 12-15 million rupiahs every month just to dispose of garbage. The similar problem also occurred in Babakan village where the community disposed of waste without any sorting it beforehand. The local people just simply dump trash openly everywhere. Once there is enough trash, they will burn them all in an open fire without sorting out any hazardous waste, such as electronic waste. After the rainy season, this burned trash will be washed away into a nearby river, which is also a key source for drinking and living water. Babakan village government has provided a waste bank as a waste processing facility for the community. However, the waste bank only functions as a recycled waste collector without processing other types of non-biodegradable waste. Non-biodegradable waste handling in MAN 2 Cirebon and Babakan Village are presented in Figure 3 and Figure 4.
Figure 3. Non-biodegradable waste handling in MAN 2 Cirebon.

Figure 4. Non-biodegradable waste handling in Babakan Ciwaringin Village.

MASARO technology presents a solution of non-biodegradable waste problem in MAN 2 Cirebon and Babakan Village with processing non-biodegradable waste in IPSA (non-biodegradable waste installation) by plastic refinery unit which is represented in Figure 5. MASARO plastic refinery processing un-recycled waste with clean and environmentally friendly technology. The plastic refinery consists of a incinerator, pyrolyzer, and wet scrubber unit. The incinerator burn waste such as woods, diapers, unrecycled papers, and etc that classified as other un-recycled waste. The incinerator is designed by utilizing the buoyancy force of air that make oxygen flow into the furnace chamber naturally. The flue gas of this incineration process will be contacted with pyrolyzer chamber directly. The low value plastic waste will be processed in the pyrolyzer installed vertically with the incinerator to maximizing exhaust gas heat for the pyrolysis process and preventing heat loss during the process. The fuel vapor flows into condenser by the top of pyrolyzer and being cooled along the spiral condenser pipe until the fuel is produced. The exhaust gas cleaning process is carried out on the wet scrubber unit clean air can be discharged into the environment through the chimney pipe.[11]

MASARO plastic refinery processes waste into a product without any residue. All non-biodegradable waste can be processed into useful products in the form of fuel, planting media, wood preservatives and organic pesticides. The fuel comes from processing low-value plastic films in pyrolyzers, planting media is the ash from incinerator processing, and wood preservative and large organic pesticides from wet scrubber wastewater treatment.
MASARO technology is applied in MAN 2 Cirebon by using one of the classrooms in the Man 2 Cirebon as IPSA. While, in Babakan village MASARO plastic refinery is placed in the Babakan village waste bank. To support the MASARO technology implementation, it is necessary to educate all school academics and villagers through MASARO Workshop so that they are more aware of clean living behavior, waste sorting according to its type, and the benefits of waste sorting. The purposes of this event are educating the importance of maintaining cleanliness, introducing MASARO, educating the waste sorting according to MASARO, and educating the benefits of waste sorting.

The implementation of MASARO technology in MAN 2 Cirebon and Babakan Village has a positive impact where students and villagers sorting waste into segregated trash bins that sorted according to MASARO. All of the non-biodegradable waste is processed at IPSA in MAN 2 Cirebon and Babakan Village waste bank. IPSA products is used by students and villagers for greening and farming by polybag farming and fulfillment of residents’ stove fuel. The implementation of MASARO non-biodegradable waste management are represented in Figure 6 and Figure 7.

**Figure 6.** MASARO Non-biodegradable waste management in MAN 2 Cirebon.

**Figure 7.** MASARO Non-biodegradable waste management in Babakan Ciwaringin Village.

3.3. **Circular Economy of MASARO Plastic Refinery**

Circular economy of MASARO technology for non-biodegradable waste can be divided by 2 path: recycle path and recovery path. Figure 8 represent MASARO circular economy for non-biodegradable...
In recycle path, valuable waste will be recycled by recycle industry to become another product for consumption. The waste becomes non-biodegradable and goes through recycle cycle again. Meanwhile, non-valuable waste in recovery path is processed to MASARO plastic refinery and converted into MASARO product such as fuel, ash for growing media, organic pesticide, wood preservative. Output from MASARO plastic refinery will be used for agriculture and machinery that use fuel. Product from farming will go through manufacturer and go through cycle again. Recycle path and recovery path are represented by Figure 9. No waste is generated by consumption of MASARO product.

**Figure 8.** MASARO circular economy diagram.

MASARO non-biodegradable waste treatment is divided into two programs, which are social and industrial program. Figure 10 represents the MASARO program with (a) MASARO’s social program and (b) MASARO’s industrial program. MASARO’s social program is started with collection of non-biodegradable waste especially other un-recycled waste type. The waste is burned in the incinerator and produced ash. The ash later be used as growth medium for polybag farming, the system that implemented in the community. The polybag system uses the 4:3:2:1 volumetric ratio, with 4 parts growth medium, 3 parts animal feces, 2 parts MASARO compost, and 1-part charcoal. The program is to use ash (product of MASARO plastic refinery) for polybag farming. The polybag farming movement by community is developed and formed Sustainable Food House/Rumah Pangan Lestari (RPL). Crop produced from RPL is used as food sources for the community. Residue of polybag farming create plastic film waste and processing crops into food also create non-biodegradable waste like food packaging. The waste created from the process becomes the source of non-biodegradable waste thus creating circular economy.

**Figure 9.** (a) MASARO recycle path, (b) MASARO recovery path.
MASARO’s industrial program represent MASARO plastic refinery as Non-biodegradable Waste Management Industry (IPSA). Non-biodegradable waste is processed in IPSA to produce 4 type of product. Non-biodegradable waste that entered IPSA is divided by two type which is un-recycled plastic waste and other un-recycled non-biodegradable waste. Plastic waste is converted into fuel that has the same quality as diesel oil. Other un-recycled waste is burned produced to produce hot gas as energy source for pyrolyzer and the recidue can be used as growth medium. Meanwhile, the condensed water used for cooling the hot gas can be used as wood preservative and organic pesticide. The product of IPSA include fuel, growing media, organic pesticide, wood preservative. Fuel from IPSA is used for machinery such as diesel engine. Meanwhile, growing media, organic pesticide, and wood preservative is used mainly in agriculture sector. The food processed from the harvested crops will generate non-biodegradable waste (from polybag and food packaging) and transferred back again into MASARO plastic refinery creating circular economy.

4. Conclusion and Future Outlook
The circular economy of non-biodegradable waste processing by MASARO technology can solve the whole problem of non-biodegradable waste in the community as a source of community income with the MASARO plastic Refinery. MASARO technology in handling non-biodegradable waste can save lots of costs production and energy consumption when compared to the current waste processing system. MASARO Plastic refinery is a very profitable and environmentally friendly to be applied in small scale or industrial scale in the future that can regenerate and explore the maximum end-of-life value of non-biodegradable material that can be used as long as possible in its life cycle.

Acknowledgements
Authors wishing to acknowledge assistance and data support from MASARO MAN 2 Cirebon, Babakan Ciwaringin Village, and Babakan Ciwaringin Waste Bank. Special thank to Dow Chemical International, USA, for the financial sponsorship of Masaro Showcase Project.

References
[1] Grigore M E 2017 Methods of recycling, properties and applications of recycled thermoplastic polymers Recycling 2(4) 24
[2] Kukreja R 2009 Advantages and disadvantages of recycling Conserve Energy Future.
[3] Sharuddin S D A, Abnisa F, Daud W M A W, Aroua M K 2016 A review on pyrolysis of plastic wastes Energy Convers. Manag. 115 308-326.
[4] Masanet E, Auer R, Tsuda D, Barillot T, Baynes A 2002 An assessment and prioritization of “design for recycling” guidelines for plastic components IEEE 5-10.

[5] Martynis M, Mulyazami, Winanda E, Harahap A N 2019 Thermal pyrolysis of propylene plastic waste into liquid fuel: reactor performance evaluation, IOP conf. ser., Mater. sci. eng. 543.

[6] Olufemi A S, Olagboye S A 2017 Thermal conversion of waste plastics into fuel Int. j. petrochem. sci. eng. 2 (8).

[7] Bridgwater A V, Review of fast pyrolysis of biomass and product upgrading 2012 Biomass Bioenergy 38 68-94.

[8] Abnisa F, Daud W M A W, A review on co-pyrolysis of biomass:nan optional technique to obtain a high-grade pyrolysis oil 2014 Energy Convers Manag 87 883-900.

[9] Kwakwa V, Chaves R A, Kemper K E, Glauber A J, Warden F V 2019 Improvement of solid waste management to support regional and metropolitan cities World Bank Project Appraisal Document.

[10] Vos M, Wullink F, Lange M, Acoleyen M, Staveren D, Meijenfeldt V. The circular economy-what is it and what does it mean for you? Arcadis Briefing Paper 2-3

[11] Abidin A Z, Manajemen sampah zero (MASARO) Indonesian Patent P00201704782

[12] Abidin A Z, Yemensia E V, Choliq N S, Hastuti R, Study on Environmental Health Aspect of Plastic Refinery in MASARO Cirebon Unit in Indonesia 2020 4th ICGEA.