Life Cycle Assesment of 3D Printing Filament from Disposable Mask

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Abstract. Disposable mask waste can decompose into the environment for hundreds of years, so waste management is needed to support sustainable and environmentally friendly products. One solution to dealing with disposable mask waste is the manufacture of 3D printing filaments. A product is said to be sustainable and environmentally friendly if it can be ascertained that the product has minimal impact on the environment. The method used to assess the environmental impact of a product is Life Cycle Assessment. This research is limited to cradle-to-gate by analyzing the manufacture of filaments made from disposable mask waste mixed with polypropylene. Based on calculations, it is known that the production of filaments made from mask waste has the potential to produce greenhouse gases, acidification, and eutrophication. However, this research can be a good step to produce products made from waste and supporting sustainability.

Keywords: Life Cycle Assessment, LCA, disposable mask, filament, 3D printing

1 Introduction

The outbreak of Covid-19 has triggered an increase in the number of single-use masks. Masks are the main protection from potential virus exposure. Data from the Indonesian Institute of Sciences shows that the amount of personal protective equipment waste, especially masks, was recorded at 1,662.75 tons in the first 6 months of the pandemic from March-September 2020 [1]. This has the potential to accumulate disposable mask waste which has a major impact on the environment [2] These masks are generally made of synthetic fabric made from Polypropylene which cannot be biodegraded. Disposable mask waste has a similar impact to other plastics when disposed of into the environment. Manufacturing of 3D printing filaments can be a solution to overcome this waste.

3D printing filament is a thermoplastic material in the form of yarn coils which is generally available in two standard diameters, namely 1.75 mm and 2.85 mm. Acrylonitrile butadiene styrene (ABS) and Polylactic acid (PLA) are the most widely used thermoplastic materials in 3D Printing applications. The use of recycled mask materials both as a whole and mixing with thermoplastics commonly used in 3D printing applications is expected to be an alternative more environmentally friendly material. In addition to reducing the amount of waste, the use of recycled materials is expected to reduce the use of new plastics, especially in 3D Printing products.

JICOMS 2022, November 16, Jakarta, Indonesia

DOI 10.4108/eai.16-11-2022.2326126

To support SDG goals 9 and 12 which emphasize economic growth and responsible consumption and production [3] which are expected to produce sustainable products and can increase product-added value, manufacturing filament from waste can be an attractive opportunity. Sustainable products are products that have minimal impact on the environment in terms of energy use and resources used [4]. The method used to estimate the environmental impact of a product is a Life Cycle Assessment (LCA) [5].

Life Cycle Assessment is a method for estimating the impact of a product, and the process during its life cycle: from raw materials to waste, and becomes a tool for estimating the inputs (raw materials and energy) for a product and the output of a product throughout its life [6]. There are 4 stages of life cycle assessment, namely goal and scope determination, life cycle inventory, life cycle impact assessment, and interpretation. Most of the literature regarding 3D printing is found related to printed products, not the manufacturing of filament, especially 3D printing filament from waste. This research was conducted to enrich the study of filaments made from waste.

In general, the recycling process for disposable masks goes through four stages, namely disinfection, removing ear rubber and nose clips, grinding extrusion, and injection [6]. One of the stages in making 3d printing filament is the extrusion process. Extrusion technology is included in additive manufacturing (AM). AM is a promising sustainable manufacturing method [7]. The AM method produces a smaller global warming potential than the conventional manufacturing method [8]. Several articles found that the AM method is related to the environment, energy, human health, product life cycle, and other sectoral issues, this method is more efficient than conventional manufacturing.

Filaments made from polylactide acid (PLA), Acrylonitrile butadiene styrene (ABS) are the most found on the market, then filaments made from Polyethylene Terephthalate (PETG) are circulating [9]. Produce these three materials, of course, emit emissions to the environment, as well as waste which is generally only disposed of or burned. Therefore, it is necessary to study a new material made from waste that is expected to be more environmentally friendly and can reduce dependence on previous materials.

2 Research Methods

This study uses the LCA method, carried out according to the standards of the methodology described in the ISO 14040 series by the International Organization for Standardization (ISO) [10]. The method consists of 4 stages: goals and scope definition, inventory analysis, impact assessment, and interpretation. This research is based on LCA is cradle-to-gate and follows the LCA approach for mask waste filaments with a Polypropylene blend. The calculation uses the GaBi application.

2.1 Goals and Scope Definition

This study aims to estimate the environmental impact of 3D printing filament production from disposable mask waste. The limit of this research is cradle-to-gate by focusing on the process of obtaining raw materials, disinfection, hot pressing masks, grinding masks, and extruded into filaments. Filament production uses a formulation of 25% mask waste and 75% PP. This process does not involve transportation because it is done in one place by using a drop mask box.

2.2 Inventory Analysis

This stage identifies each stage in the production process, starting from the disinfection process to extruding masks into 3D printing filaments. Inputs of AM method are energy and material [8]. Every material and energy needed to produce 1 kg of masks is calculated by taking primary data. Figure 1 shows a flowchart of the production process for filaments made from disposable mask waste.

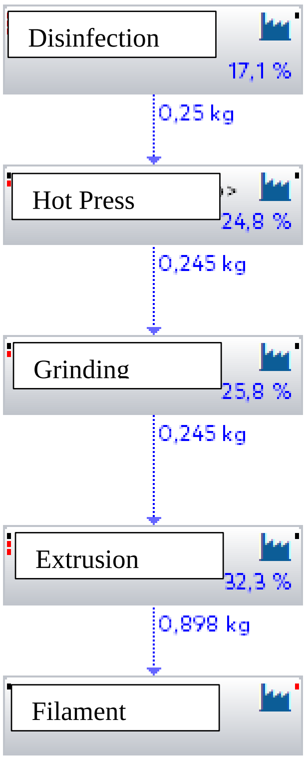

Fig 1. Production Flowchart of 3D printing filament from disposable mask waste

Table 1. Life cycle inventory of filament 3D printing production from disposable mask waste

No	Stage of production 1000g (1kg)	Unit	M 25 : PP 75
1	**Materials**		
	‘Disposable mask waste	gram	250,00
	Disposable mask waste after press	gram	250,00
	Weight of disposable mask waste	gram	245,00
	PP	gram	750,00
2	**electricity needed**		
	Hot press of disposable mask waste	kWh/Kg	1,97
	Grinding of disposable mask waste	kWh/Kg	2,10
	Filament extrusion	kWh/Kg	2,52
	Eelctricty total	kWh/Kg	6,59
3	**Weight total of filament**	kg	0,898

2.3 Impact Assessment

Impact assessment provides a quantification of the environmental impact of a product [11]. Quantification of environmental impacts using GaBi software which is calculated using the CML method. Impact assessments include: potential climate change, freshwater ecotoxicity, human toxicity, ozone depletion, particle formation, terrestrial acidification, and water depletion. For endpoints the cumulative value assessment for ecosystem quality, human health and resources was considered. General environmental impact quantification is listed in table 2.

Table 2. Impact assesment of filament 3D printing production from disposable mask waste

	Filament 3D Printing Production <LC>	Filament 3D Printing Production <LC> Disinfection <u-so>	Filament 3D Printing Production <LC> Extrusion <u-so>	Filament 3D Printing Production <LC> grinding <u-so>	Filament 3D Printing Production <LC> Press <u-so>
Global Warming Potential (GWP 100 years) [kg CO2 eq.]	6.14	1.05	1.98	1.58	1.53
Acidification Potential (AP) [kg SO2 eq.]	0.00911	0.00155	0.00293	0.00234	0.00229
Eutrophication Potential (EP) [kg Phosphate eq.]	0.00237	0.000404	0.000761	0.000608	0.000595

3. Result and Discussion

Figure 2 shows the environmental and human health impacts resulting from the manufacture of 3D printing filaments made from disposable mask waste, namely: A climate change, B potential for acidification, and C potential for eutrophication. Based on calculations, it is known that the manufacture of 1 kg of 3D printing filament from disposable mask waste contributes to a global warming potential of 6.14 kg CO2-eq. The stage that contributed the most to GWP was construction activities at 32.3%. One of the most widely used materials in the manufacture of 3D printing filaments is PLA [11]. Morão and de Bie stated that the GWP produced in PLA production reached 501 kg CO2-eq/ Ton PLA. So it can be seen that filaments made from disposable mask waste can be an alternative material that is quite environmentally friendly. One strategy to reduce the GWP value generated in the manufacture of filaments made from disposable masks can be overcome by shortening the process, for example by educating on mask disinfection from home so that when given to the waste collection box the masks are already in a disinfected condition.

In addition to generating global warming potential, the manufacture of 3D printing filaments from disposable mask waste has a potential acidification impact. Acidification is caused by air emissions of NH3, NO2, and Sox which, if precipitated, can affect soil acidity. Based on Figure 2 (B) it is known that acidification comes from SO2 emission of 0.00911 kg SO2-eq which is mostly produced in the hot press process. The manufacture of this filament also produces 0.00237 kg of phosphate-eq which has an impact on the potential for eutrophication of waters and land. Based on the data, the extrusion stage produces the highest eutrophication potential compared to the other stages. This value is affected by using electricity and other heated chemical materials.

The manufacture of 3D printing filaments generates global warming potential. However, if you look at the GWP generated from disposable masks of 6.55E+00 kg CO2-eq [12], making filament from disposable mask waste can be an alternative to reducing the potential for global warming. The decrease in GWP can be more significant if the stages in the production process are not too long, one of which is through education on mask disinfection at home. Disposable masks are generally made of polypropylene and decompose for approximately 450 years [13] so the manufacture of this filament can be a solution to overcome the accumulation of disposable mask waste.

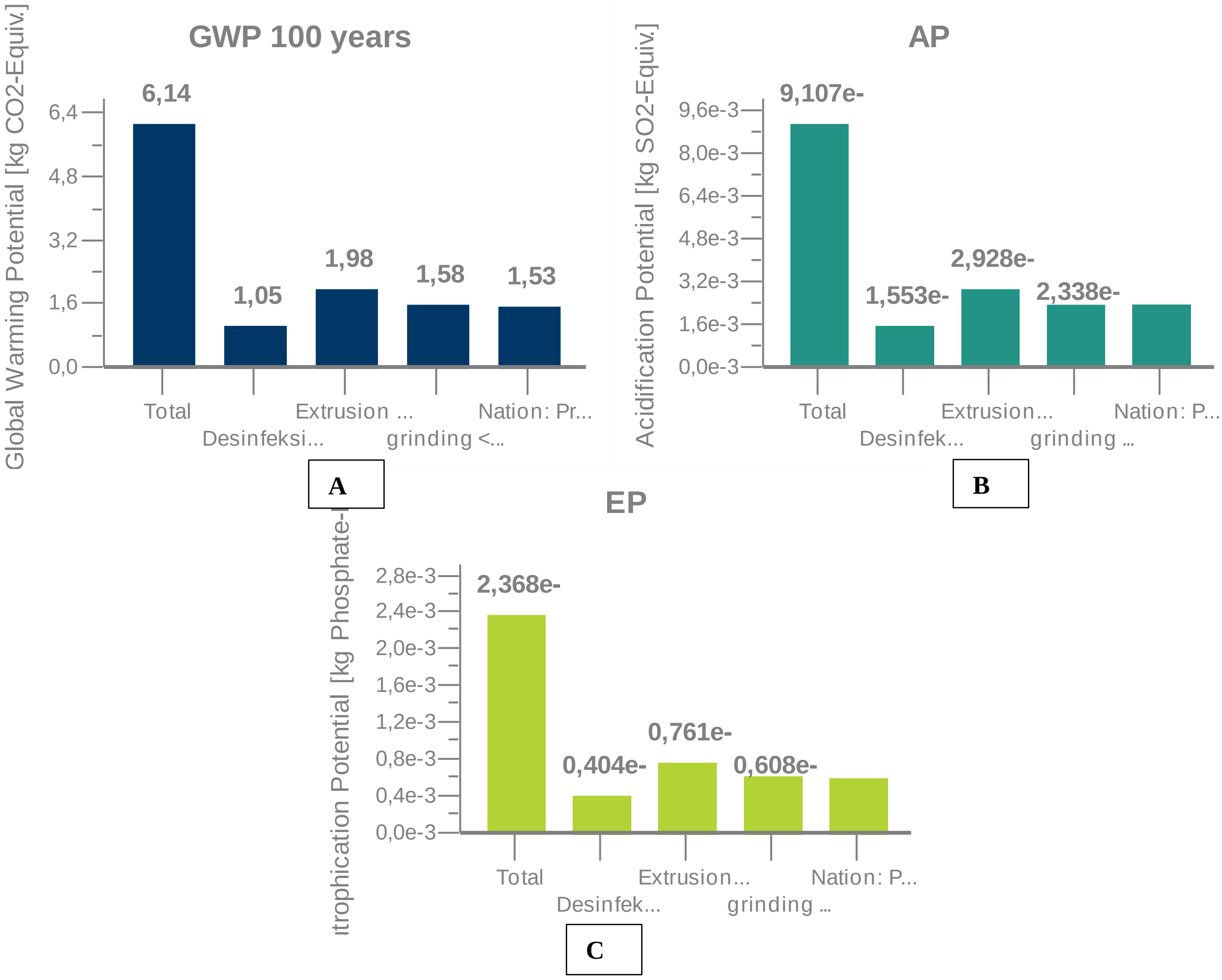

Fig 2. Assessment result

4. Conclusion

Based on estimates, it is known that making 3D printing filaments from disposable mask waste can be an environmentally friendly alternative material. After being quantified, it is known that the manufacture of 3D printing filaments contributes a GWP of 6.14 Kg CO2-eq. . However, if you look at the GWP generated from disposable masks of 6.55E+00 kg CO2-eq, making filament from disposable mask waste can be an alternative to reducing the potential for global warming. Recycling becomes the most profitable method to increase the added value of products made from waste and is in line with the circular economy concept [14].

Acknowledgments
The authors would like to acknowledge the funding by the Lembaga Pengelola Dana Pendidikan (LPDP), Indonesian Ministry of Finance through applied for research funding.

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